Chapter 6
Industry, Technology, and the Global Marketplace

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Highlights

Knowledge- and Technology-Intensive Industries in the World Economy

Knowledge- and technology-intensive (KTI) industries have been a major and growing part of the global economy. The United States has the highest KTI share of gross domestic product (GDP) of any large economy.

- ♦ Ten KTI industries, consisting of five service industries and five high-technology (HT) manufacturing industries, represented 27% of world GDP in 2012. Among the KTI industries, the commercial knowledge-intensive (KI) services—business, financial, and communications—have the highest share (16% of GDP). The public KI services, education and health, have a 9% share. The five HT manufacturing industries—aircraft and spacecraft; communications and semiconductors; computers; testing, measuring, and control instruments; and pharmaceuticals—have a 2% share.
- ♦ The U.S. economy had the highest concentration of KTI industries among major economies (40% of U.S. GDP). The KTI concentrations for the European Union (EU) and Japan were considerably lower at 29%–30%.
- ♦ Major developing countries have lower KTI shares than developed countries. The KTI shares in Brazil, China, and India were 19%–21%. Turkey had the highest KTI share (23%) among larger developing countries.

Productivity growth in the world's developing countries since 2000 has been much faster than in developed countries.

- ♦ Labor productivity growth in developing countries accelerated from 2% in the early 2000s to 6% in the mid-2000s before falling to 4% in the latter half of the 2000s. China and India led productivity growth of developing countries, growing 10% and 6%, respectively, between 2003 and 2012.
- ♦ Labor productivity growth in the United States and other developed countries slowed from 2% in the early 2000s to negative growth during the global recession before rising to 1%.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

The United States is the largest global provider of commercial KI services and HT manufactured goods.

- ♦ The United States has the largest global share (32%) in commercial KI services industries (business, financial, and communications). The EU is the second-largest global provider (23%).
- ♦ China's commercial KI services industries have been growing rapidly, but from a low base. China's global share reached 8% in 2012 to tie with Japan as the third-largest global provider.
- ♦ In HT manufacturing, the United States has a global share of 27%, closely followed by China. China's HT industries have grown exponentially from a global share of 4% in 2000 to 24% in 2012.

U.S. KTI industries generally fared better than those of the developed economies in the EU and Japan in the aftermath of the recession.

- ♦ The U.S. commercial KI services industries did better than their EU competitors following the 2008–09 global recession. U.S. value-added output in these industries grew 9% in 2010–12, whereas value added in the EU was stagnant.
- ♦ U.S. HT manufacturing industries fared better than those in the EU or Japan following the 2008–09 global recession. U.S. value-added output grew 2% in 2010–12, while value-added output of the EU and of Japan remained flat or declined.

U.S. KTI industries are a major part of the U.S. economy, and they have mostly recovered from the recession.

- ♦ U.S. commercial KI services industries employ one of every seven U.S workers (18 million) and pay higher-than-average wages. These industries have a higher-than-average share of skilled workers and fund about one-fourth of U.S. business R&D.
- ♦ Although U.S. HT manufacturing industries are much smaller than commercial KI services, they fund nearly one-half of U.S. business R&D. These industries employ 1.8 million workers and have an even higher share of highly skilled workers than commercial KI services.
- ♦ The value-added outputs of U.S. commercial KI services and HT manufacturing in 2012 are higher than their levels prior to the recession. However, employment in U.S. commercial KI services and HT manufacturing industries remains below its pre-recession levels.

Trade and Other Globalization Indicators

The EU is the world's largest exporter of commercial KI services, followed by the United States. Both the EU and the United States have substantial surpluses.

- ♦ The EU's commercial KI services exports more than doubled to reach $432 billion between 2004 and 2011, with its surplus widening to $127 billion.
- ♦ U.S. exports of commercial KI services grew as fast as the EU's to reach $235 billion between 2004 and 2011; the U.S trade surplus climbed from $25 billion to $52 billion.
- ♦ Commercial KI services exports of developing countries grew much faster than developed countries, but from a much lower base. In these services, China and India have the largest export shares (4%–5% each) among developing countries. India's trade surplus widened from $11 billion in 2004 to $51 billion in 2011.

In HT manufactured goods, China is the world's largest exporter, followed by the EU and the United States.

- ♦ China, the world's second-largest manufacturer of electronic products, is the world's largest exporter of HT products, with a surplus of over $200 billion. China imports components and inputs from the United States, the EU, and Asia for final assembly in China.

- The U.S. share of global HT exports remained stable for much of the 2000s. However, the U.S. trade deficit in HT products widened from $50 billion to $130 billion during this period.
- The U.S. trade deficit in HT goods is almost entirely due to information and communications technologies (ICT) products—communications, computers, and semiconductors. In other HT manufactured goods, notably aircraft and spacecraft, the United States has a substantial trade surplus.

A separate measure of U.S. trade in advanced technology products (ATP) shows patterns similar to those found in internationally comparable HT product trade data.

- In 2012, the United States exported $305 billion of ATP and imported $396 billion of ATP products. The $92 billion deficit of ATP trade is largely due to trade in ICT products, primarily with China. The United States has a substantial surplus in trade of aerospace products.

U.S. overseas investment in foreign KTI industries exceeds foreign investment in U.S. KTI industries.

- In the commercial KI services industries, the stock of U.S. overseas investment was $1 trillion in 2012. The EU is the largest recipient, followed by Asia, which in these data includes Australia and New Zealand. The stock of foreign direct investment in the United States in these industries was $600 billion, with the EU as the largest investor.
- In computer and electronics manufacturing, which includes three HT manufacturing industries, the stock of U.S. overseas investment was $102 billion. Asia, which in these data includes Australia and New Zealand, and the EU are the two largest destinations. The stock of foreign direct investment in these industries in the United States was $61 billion, with the EU and Asia and the Pacific regions being the two largest investors.

Innovation-Related Indicators of the United States and Other Major Economies

U.S. firms in commercial KTI industries reported much higher incidences of innovation than firms in other industries.

- Five HT manufacturing industries—aircraft; computers; communications; testing, measuring, and control instruments; and pharmaceuticals—reported rates of product innovation that were at least double the U.S. manufacturing sector average.
- In the U.S. nonmanufacturing sector, software firms were the leading innovators, with 69% of companies reporting the introduction of a new product or service compared to the 9% average for all nonmanufacturing companies. Innovation is two to three times higher than the nonmanufacturing average in computer systems design; data processing, hosting, and related services; and scientific R&D services.

The U.S. Patent and Trademark Office (USPTO) granted U.S. inventors 127,000 patents in 2012, not quite half of all USPTO patents granted worldwide.

- The share of patents granted by USPTO to U.S. inventors declined from 53% in 2003 to 48% in 2012.
- The United States has a higher concentration relative to other major economies in USPTO patenting activity in several advanced and science-based technologies, including ICT, automation, biotechnology, and pharmaceuticals.

The United States has a similar share to the EU and Japan in triadic patents, which are considered an indicator of higher-value inventions.

- Triadic patents are patents sought for protection in the world's largest markets—the United States, the EU, and Japan.
- The U.S. share of triadic patents has remained constant during the 2000s at 27%–30%.

Investment and Innovation in Clean Energy Technologies

More of the world's investment in clean energy technologies occurred in developing countries than in developed countries in 2012. More commercial investment in clean energy technologies occurred in China than in any other country.

- Clean energy investment in China, largely in solar and wind technologies, rose exponentially over the last decade to reach $61 billion in 2012.
- Commercial investment in clean energy was between $27 billion and $29 billion in the United States and the EU in 2012. Commercial investment in the EU is down sharply due to the EU's economic difficulties and cutbacks in government support for clean energy production and investment.
- Worldwide venture capital investment in clean energy technologies was estimated at $4 billion in 2012. The United States is the largest recipient, accounting for more than 80% of all investment. Three technologies—energy smart and efficiency, solar, and biofuels—dominate venture capital investment.
- Worldwide venture capital investment rose rapidly, more than quadrupling from $1 billion to $4 billion from 2004 to 2012.

The United States and Japan were the largest investors in 2012 public research, development, and demonstration (RD&D) for clean energy technologies.

- Expenditures of most OECD countries on RD&D investment for clean energy and nuclear technologies were an estimated $13 billion in 2010.
- U.S. public RD&D investment in clean energy technologies jumped from $1.5 billion in 2004 to spike at $7.0 billion in 2009 due to one-time stimulus funding under the American Recovery and Reinvestment Act of 2009. In 2011, U.S. public RD&D dropped to $4.0 billion, still $2.5 billion higher than its level in 2004.

Introduction

Chapter Overview

Policymakers in many countries increasingly emphasize the central role of knowledge, particularly research and development and other activities that advance science and technology (S&T), in a country's economic growth and competitiveness. This chapter examines the downstream effects of these activities on the performance of the United States and other major economies in the global marketplace.

This chapter covers two main areas. The first is knowledge- and technology-intensive (KTI) industries in both the service and manufacturing sectors. KTI industries are 10 categories of industries classified by the Organisation for Economic Co-operation and Development (OECD 2001, 2007) that have a particularly strong link to S&T:[1]

- Five knowledge-intensive (KI) services industries incorporate high technology (HT) either in their services or in the delivery of their services. Three of these—financial, business, and communications services (including computer software and R&D)—are generally commercially traded. The others—education and health services—are publicly regulated or provided and remain relatively more location bound.
- Five HT manufacturing industries spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D. These are aircraft and spacecraft, pharmaceuticals, computers and office machinery, semiconductors and communications equipment (treated separately in the text), and scientific (medical, precision, and optical) instruments.[2] Trends in aircraft and spacecraft and pharmaceuticals are particularly sensitive to government policies. Aircraft and spacecraft trends are affected by funding for military aircraft, missiles, and spacecraft and by different national flight regulations. National regulations covering drug approval, prices, patent protection, and importation of foreign pharmaceuticals can affect pharmaceuticals.

This report gives special attention to KTI industries in information and communications technology (ICT). ICT combines the HT manufacturing industries of computers and office machinery, communications equipment, and semiconductors with the KI services of communications and computer programming (a subset of business services). ICT industries are important because they provide the infrastructure for many social and economic activities, facilitating innovation and economic growth.[3]

Industries that are less KTI, however, remain very important in the world economy and therefore receive some attention in the chapter (see sidebar, "Industries That Are Not Knowledge or Technology Intensive").

The globalization of the world economy involves the rise of new centers of KTI industries.[4] Although the United States continues to be a leader in these industries, China, India, Brazil, and other developing economies have vigorously pursued national innovation policies in an effort to become major producers and exporters of KTI goods and services. Advances in S&T have enabled companies to spread KTI activity to more locations around the globe and to develop strong interconnections among geographically distant entities.

The second major focus of the chapter is innovation. Because innovation is closely associated with technologically led economic growth, the analysis of innovation in the chapter emphasizes the role of KTI industries. The measurement of innovation is an emerging field, and current data and indicators are limited. However, activities related to the commercialization of inventions and new technologies are regarded as important components of innovation indicators. Such activities include patenting, the creation and financing of new HT firms, and investment in intangible goods and services.

In recent years, innovations aimed at developing improved technologies for generating clean and affordable energy have become increasingly important in both developed and developing countries or economies. Clean energy has a strong link to S&T. Like ICT, energy is a key element of infrastructure, the availability of which can strongly affect prospects for growth and development. For these reasons, the chapter pays special attention to energy technologies.

Several themes cross-cut the various indicators examined in the chapter:

- The HT manufacturing industries are the most globalized among the KTI industries. Two HT manufacturing industries—communications; semiconductors and computers—have the most complex global value chains, where China is the dominant locale for final production. Three industries—aircraft and spacecraft; testing, measuring, and control instruments; pharmaceuticals—are less globally integrated, with final production largely located in developed countries.
- Globalization is increasing rapidly in the commercial KI services industries but remains substantially less than in the HT manufacturing industries. Data on trade and U.S. foreign investment suggest that these industries have substantial linkages among developed economies. Industries in developed economies also contract out some of their activities to developing economies.
- Although KTI activity has increased in Brazil, India, Indonesia, Turkey, and other developing countries, China plays a unique role in this arena. Despite a per capita income comparable to that in other developing countries, China's economic activity in several KTI industries has grown unusually quickly and is now comparable to or exceeds that of the United States, the European Union (EU; see "Glossary" for member countries), and Japan.
- KTI industries remain concentrated in developed countries despite much more rapid growth by China and other developing countries. Developed countries account for

Industries That Are Not Knowledge or Technology Intensive

Science and technology (S&T) are used in many industries besides high-technology (HT) manufacturing and knowledge-intensive (KI) services. Service industries not classified as KI services—which include the wholesale and retail, restaurant and hotel, transportation and storage, and real estate industries—may incorporate advanced technology in their services or in the delivery of their services. Manufacturing industries not classified as HT by the Organisation for Economic Co-operation and Development (OECD) may use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacture, and/or perform or rely on R&D. Industries not classified as either manufacturing or services—agriculture, construction, mining, and utility—also may incorporate recent S&T in their products and processes. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining depends on earth sciences, and utilities rely on advances in energy science.

In the non-KI services industries—real estate; restaurants and hotels; transport and storage; and wholesale and retail—patterns and trends of the four largest producers—the United States, the EU, Japan, and China—were similar to those in HT manufacturing and commercial KI services (table 6-A). The United States and the EU, the

Table 6-A
Global value added for selected industries, by selected region/country/economy: 1997, 2006, and 2012
(Percent distribution)

Service industry and region/country/economy	1997	2006	2012
Agriculture			
Global value added (current $billions)	1,140	1,461	2,879
China	15.3	20.6	28.8
EU	19.5	15.6	10.3
Japan	6.6	4.4	3.8
United States	9.5	8.4	5.9
Construction			
Global value added (current $billions)	1,610	2,585	3,657
China	4.0	6.2	16.3
EU	27.2	31.1	22.4
Japan	21.3	10.6	10.6
United States	21.5	25.2	15.3
Mining			
Global value added (current $billions)	573	1,713	3,038
China	4.8	8.2	17.4
EU	11.7	7.4	3.9
Japan	1.2	0.2	0.1
United States	16.6	13.4	9.4
Real estate			
Global value added (current $billions)	2,686	4,283	5,667
China	1.7	3.2	8.3
EU	29.3	32.7	27.8
Japan	17.3	12.1	13.1
United States	34.3	34.8	31.9
Restaurants and hotels			
Global value added (current $billions)	732	1,202	1,708
China	3.3	5.5	10.2
EU	28.2	31.6	25.9
Japan	17.5	10.9	11.3
United States	30.1	32.0	27.6
Transport and storage			
Global value added (current $billions)	524	855	1,255
China	3.8	6.0	10.4
EU	30.5	34.6	26.8
Japan	14.2	8.6	9.3
United States	23.9	20.2	16.7
Utilities			
Global value added (current $billions)	708.2	1,032.8	1,487.8
China	4.0	9.5	20.5
EU	25.0	26.5	20.9
Japan	21.4	14.0	11.7
United States	26.7	24.8	19.7
Wholesale and retail			
Global value added (current $billions)	3,713	5,607	8,042
China	3.0	4.5	10.7
EU	24.9	26.1	20.5
Japan	18.5	11.3	9.9
United States	30.0	30.4	23.7

EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2013).

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three-quarters of global production of commercial KI services industries, the largest category of KTI industries.

- KTI industries in developing countries have fared better than those in developed countries in the aftermath of the 2008–09 global recession. Among the KTI industries in the developed countries, those in the United States rebounded more robustly from the economic downturn than those in other developed economies.

Chapter Organization

The chapter focuses on the United States, the EU, Japan, and the large and rapidly developing economy of China. Other major developing countries, including Brazil, India, and Indonesia, also receive significant attention. The timespan is from the late 1990s to the present.

This chapter is organized into five sections. The first section discusses the prominent role of KTI industries in regional and national economies around the world.

Industries That Are Not Knowledge or Technology Intensive—continued

two largest providers, had modest declines in their global shares of value added between 1997 and 2012. Japan's share declined more sharply. China's global share grew rapidly to reach near or at Japan's share in restaurants and hotels, transport and storage, and wholesale and retail during this period.

Non-HT manufacturing industries are divided into three categories, as classified by the OECD: medium-high technology, medium-low technology, and low technology.* In these industries, patterns and trends were somewhat divergent from those in HT manufacturing (table 6-B). China's global share of value added grew rapidly between 1997 and 2012, and it became the world's largest manufacturer in the three non-HT manufacturing segments. The global shares of the United States and EU declined sharply in contrast to their relatively more stable positions in HT manufacturing. Japan's share also declined sharply in all three segments.

The positions of the United States, the EU, China, and Japan in nonmanufacturing and nonservices industries—agriculture, construction, and mining—are fairly similar to their positions in KTI industries (table 6-A). China's global share grew rapidly between 1997 and 2012, and it became the world's largest producer in agriculture and mining. The global shares of the United States and EU fell moderately. Japan had a steeper decline in these industries.

* Medium-high technology includes motor vehicle manufacturing and chemicals production, excluding pharmaceuticals; medium-low technology includes rubber and plastic production and basic metals; and low technology includes paper and food product production.

Table 6-B
Global value added for manufacturing industries, by selected technology level and selected region/country/economy: Selected years, 1997–2012
(Percent distribution)

Manufacturing technology level and region/country/economy	1997	2003	2006	2009	2012
Medium high					
Global value added (current $billions)	1,467	1,643	2,139	2,357	3,480
China	3.4	7.0	11.6	23.1	28.2
EU	33.2	33.9	32.4	28.0	23.0
Japan	20.2	16.8	14.3	11.8	11.6
United States	23.4	23.7	20.3	15.3	14.4
Medium low					
Global value added (current $billions)	1,346	1,482	2,212	2,418	3,512
China	3.8	7.8	12.9	24.0	31.1
EU	28.9	29.6	25.8	22.1	16.2
Japan	19.5	15.1	11.3	9.8	9.6
United States	23.5	22.4	20.2	14.9	13.4
Low					
Global value added (current $billions)	1,454	1,594	1,955	2,371	2,969
China	4.6	8.1	13.4	20.4	29.1
EU	30.2	30.0	27.9	25.1	19.3
Japan	15.7	13.4	10.0	9.6	9.1
United States	23.4	24.1	20.6	17.9	13.9

EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The technology level of manufacturing is classified by the Organisation for Economic Co-operation and Development on the basis of R&D intensity of output. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2013).

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The second section describes the global spread of KTI industries and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry group as a whole, for KI services and HT manufacturing overall, and for particular services and manufacturing industries within these groups. Because advanced technology is increasingly essential for non-HT industries, some data on these industries are also presented.

The third section examines indicators of increased interconnection of KTI industries in the global economy. Data on patterns and trends in global trade in KTI industries make up the bulk of this section. The section also presents data on U.S. trade in advanced technology products (ATP), examining trends in U.S. trade with major economies and in key technologies. Data on domestic and foreign production and on employment in U.S. multinational companies (MNCs) in KTI industries are presented as indicators of the increasing involvement of these economically important firms in cross-border activities. To further illustrate the effects of globalization on the United States, the section presents data on U.S. and foreign direct investment abroad, showing trends by region and for individual KTI industries.

The fourth section presents innovation-related indicators. It examines countries' shares in all patents granted by the United States in various technology areas. It next examines countries' shares of high-value patents. It presents innovation-related data on U.S. industries from the National Science Foundation's (NSF's) Business R&D and Innovation Survey (BRDIS). A discussion of U.S. HT small businesses includes data on the number of HT small business startups and existing firms, employment, and venture capital and Small Business Innovation Research (SBIR) investment by industry.

The last section presents data on clean energy and energy conservation and related technologies, which have become a policy focus in developed and developing nations. These energy technologies, like KTI industries, are closely linked to scientific R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in the United States and other major economies.

Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The sidebar "Comparison of Data Classification Systems Used" describes these systems and aims to clarify the differences among them. The discussion of regional and country patterns and trends includes examination of developed and developing countries using the World Bank's per capita income classification. Countries classified by the World Bank as *high income* are developed countries, while those classified in the other income levels—*upper middle income, lower middle income,* and *low income*—are classified as developing. In this chapter, "country" and "economy" are used interchangeably in these discussions.

Knowledge- and Technology-Intensive Industries in the World Economy

The first section of this chapter examines the role of KTI industries in the global economy. (For an explanation of KTI industries, please see "Chapter Overview.") Data on value added in these industries can be used to examine their growing importance in the global economy, the United States, and other major economies. (For a discussion of value added and other measures of economic activity, see sidebar, "Industry Data and Terminology"). For context, selected data are presented on wealth, productivity growth, and ICT infrastructure of selected economies, with a focus on the United States and other economies in which KTI industries play a particularly large or rapidly growing role.

Growth of Knowledge- and Technology-Intensive Industries in the World and Major Economies

KTI industries—commercial KI services, public KI services, and HT manufacturing—are a major part of the global economy, making up 27% of world gross domestic product (GDP) (appendix tables 6-1–6-3). Among the KTI industries, the commercial KI services—business, financial, and communications—have the highest share (16% of GDP) (appendix table 6-4).

The public KI services—education and health—are the second largest (9%) (appendix tables 6-3, 6-5, and 6-6).[5] The HT manufacturing industries—aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring and control instruments—are much smaller, with a 2% share (appendix table 6-7).

The KTI share of the world economy remained roughly constant between 1997 and 2012 (appendix tables 6-2 and 6-3). Among the KTI categories, the commercial KI services share gained 1 percentage point to reach 16% (appendix table 6-4). The expansion of commercial KI services reflects the continued shift in developed economies to services and the tendency for businesses and other organizations to purchase various services rather than maintain organizational units to provide them. This has spurred the growth of the business services industry. In developing economies, rapid economic growth and higher per capita income have stimulated demand for various services, including the commercial KI services of communications and financial services.

The share of public KI services stayed stable at 9% between 1997 and 2012 (appendix tables 6-3, 6-5, and 6-6). The growth of education and health care in line with world GDP growth has occurred due to increased demand for and access to education and health care services, the aging of populations in many countries, and other demographic factors and technological advances, such as online education and electronic medical records. The share of HT manufacturing declined 1 percentage point to reach 2% (appendix table 6-7).

Comparison of Data Classification Systems Used

Topic	Data provider	Variables	Basis of classification	Coverage	Methodology
Knowledge-intensive (KI) service and high-technology (HT) manufacturing industries	IHS Global Insight, World Industry Service database (proprietary)	Production, value added	Industry basis using International Standard Industrial Classification	KI services—business, financial, communications, health, and education services HT manufacturing—aircraft and spacecraft, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment	Uses data from national statistical offices in developed countries and some developing countries and estimates by IHS Global Insight for some developing countries
Trade in commercial KI services	World Trade Organization	Exports and imports	Product basis using Extended Balance of Payments Services Classification	KI services—business, financial, communications, and royalties and fees	Uses data from national statistical offices, International Monetary Fund, and other sources
Trade in HT goods	IHS Global Insight, World Trade Service database (proprietary)	Exports and imports	Product basis using Standard International Trade Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific and measuring instruments	Uses data from national statistical offices and estimates by IHS Global Insight
U.S. trade in advanced-technology products	U.S. Census Bureau	Exports and imports	Product basis using Harmonized Commodity Description and Coding System, 10 technology areas classified by U.S. Census	Advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, nuclear technology, optoelectronics, and weapons	Data collected from automated reporting by U.S. Customs
Globalization of U.S. multinationals	U.S. Bureau of Economic Analysis (BEA)	Value added, employment, and inward and outward direct investment	Industry basis using North American Industrial Classification System (NAICS)	Commercial KI services—business, financial, communications HT manufacturing—aerospace, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment	BEA annual surveys of U.S. multinationals and U.S. subsidiaries of non-U.S. multinationals
U.S. industry innovation activities	National Science Foundation, Business R&D and Innovation Survey	Innovation activities	U.S. businesses with more than five employees	Industries classified on industry basis using NAICS	Survey of U.S.-located businesses with more than five employees using nationally representative sample

Continued on following page

Comparison of Data Classification Systems Used—continued

U.S. Patent and Trademark Office (USPTO) patents	The Patent Board	Patent grants	Inventor country of origin, technology area as classified by The Patent Board	More than 400 U.S. patent classes, inventors classified according to country of origin and technology codes assigned to grant	Source of data is USPTO
Triadic patent families	Organisation for Economic Co-operation and Development (OECD)	Patent applications	Inventor country of origin and selected technology area as classified by OECD	Broad technology areas as defined by OECD, inventors classified according to country of origin	Sources of data are USPTO, European Patent Office, and Japanese Patent Office
Venture capital	Dow Jones VentureSource	Investment, technology area, country of investor origin	Technology areas as classified by Dow Jones classification system	Twenty-seven technology areas, investment classified by venture firms' country location	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals

Industry Data and Terminology

The data and indicators reported here permit the tracing and analysis of broad patterns and trends that shed light on the spread and shifting distribution of global knowledge- and technology-intensive (KTI) capabilities. The industry data used in this chapter derive from a proprietary IHS Global Insight database that assembles data from the United Nations (UN) and the Organisation for Economic Co-operation and Development to cover 70 countries in a consistent way. IHS estimates some missing data for some of the developing countries, including China. Data for developing countries may not be available on a timely basis or for specific industries.

The industry data follow the International Standard Industrial Classification, a UN system for classifying economic activities. Firms are classified according to their primary activity; a company that primarily manufactures pharmaceuticals, for example, but also operates a retail business would have all of its economic activity counted under pharmaceuticals.

Production is measured as value added. Value added is the amount contributed by an economic entity—country, industry, or firm—to the value of a good or service. It excludes purchases of domestic and imported supplies as well as inputs from other countries, industries, or firms.

Value added is measured in current dollars. For countries outside the United States, value added is recorded in the local currency and converted at the prevailing nominal exchange rate. Industry data are reported in current dollar terms because most KTI industries are globally traded and because the majority of international trade and foreign direct investment is dollar denominated. However, current dollars are an imperfect measure. Economic research has found a weak link between nominal exchange rates of countries' currencies that are globally traded and differences in their economic performance (Balke, Ma, and Wohar 2013). In addition, the exchange rates of some countries' currencies are not market determined.

Value added is also an imperfect measure. It is credited to countries or regions based on the reported location of the activity, but globalization and the fragmentation of supply chains mean that the precise location of an activity is often uncertain. Companies use different reporting and accounting conventions for crediting and allocating production performed by their subsidiaries in foreign countries. Moreover, the value added of a diversified company's activity is assigned to a single industry based on the industry that accounts for the largest share of the company's business. However, a company classified as manufacturing may include services, and a company classified in a service industry may include manufacturing or may directly serve a manufacturing company. For China and other developing countries, industry data may be estimated by IHS Global Insight or may be revised frequently because of rapid economic change or improvements in data collection by national statistical offices. Thus, value-added trends should be interpreted as broad and relatively internally consistent indicators of the changing distribution of where economic value is generated, and small differences and changes should not be overemphasized.

Patterns and Trends of Knowledge- and Technology-Intensive Shares of Developed Economies

The KTI share of developed economies is much higher than that of developing economies due to their much larger share of KI services (figure 6-1; appendix tables 6-2 and 6-3). KTI shares vary widely among developed economies:

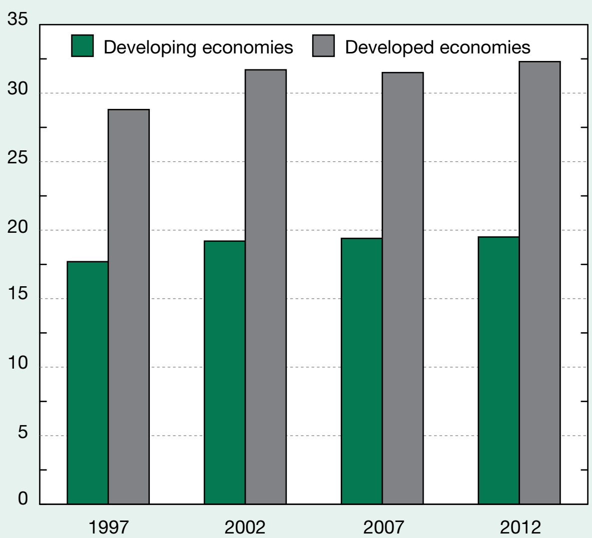
- The United States has the largest KTI share of any large developed economy (40%), followed by Australia (39%) and the United Kingdom (36%) (figure 6-2). These countries have larger shares in KI services, particularly in commercial KI services (22%–28%). The commercial KI services' shares of Australia and the United States are due, in part, to their higher shares in financial services (14% and 8%, respectively) relative to other developed economies (appendix tables 6-3 and 6-8). Some research suggests that the large size of financial sectors in the United States and other developed economies has fostered slowed economic growth and greater economic instability (Palley 2007:2–3).
- The EU, Japan, Canada, and South Korea have KTI shares of 29%–30%, with considerably smaller shares than the United States in commercial KI services (14%–18% versus 24%) (figure 6-2). The EU and South Korea have smaller shares of financial services (5%–7%) compared to Australia and the United States.

Between 1997 and 2012, the KTI share of developed economies grew from 29% to 32% due to increases in the commercial and public KI services (figure 6-1; appendix tables 6-2–6-6). The HT manufacturing share fell from 3% to 2% (appendix table 6-7). The context for this development is the continued shift from manufacturing to services in developed economies.

Trends in the KTI share varied somewhat among the developed economies:

- The KTI shares of the United States, the United Kingdom, and Australia rose 6–9 percentage points from 1997 to 2012 to reach 39%–40% in Australia and the United States and 36% in the United Kingdom (figure 6-2; appendix

Figure 6-1
KTI industries' share of GDP of developed and developing economies: Selected years, 1997–2012



GDP = gross domestic product; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include knowledge-intensive (KI) services and high-technology (HT) manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. HT industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Developed countries are classified by the World Bank as high income. Developing economies are classified by the World Bank as higher- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2012). See tables 6-2 and 6-3.

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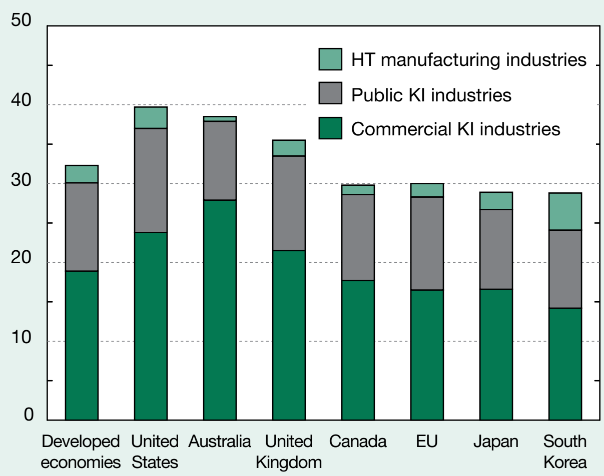
Figure 6-2
Output of KTI industries as a share of GDP of selected developed economies: 2012



EU = European Union; GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and measuring, testing, and control instruments. Developed economies are classified by the World Bank as high income.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-3–6-7.

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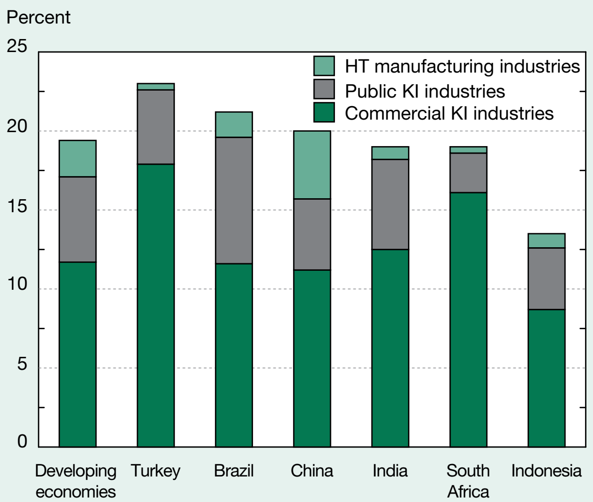
tables 6-2 and 6-3). In the United States, the increase in the KTI share occurred largely from a rise in the share of financial services (from 7% to 8%) and public KI services (from 11% to 13%) (appendix tables 6-5, 6-6, and 6-8).

- The EU's and Japan's KTI shares rose 3 percentage points to reach 30% and 29%, respectively.
- South Korea's share rose 6 percentage points to reach 29%.

Patterns and Trends of Knowledge- and Technology-Intensive Shares of Developing Economies

The KTI share of developing economies is much lower than that of developed economies due to smaller shares of KI services (figure 6-1). The KTI shares of individual developing countries vary widely, reflecting considerable differences in their stage of development and level of per capita income (figure 6-3; appendix tables 6-2 and 6-3). Among the larger developing countries, Turkey, which has a relatively high per capita income, has the highest KTI share (23%). Five countries—Brazil, China, India, Mexico, and South Africa—have KTI shares of 19%–21%. Indonesia has the lowest KTI share of any large developing economy (14%).

Figure 6-3
Output of KTI industries as a share of GDP for selected developing economies: 2012



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services included education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and measuring, testing, and control instruments. Developing economies are classified by the World Bank as higher- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-3–6-7.

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The KTI share of developing countries as a group edged up from 18% to 20% between 1997 and 2012 (figure 6-1). The commercial KI share grew slightly from 11% to 12%. The shares of public KI services and KI services were flat, as were shares of HT and non-HT manufacturing (figure 6-4). The shares of agriculture, construction mining, and utilities grew substantially in many of these countries, reflecting the continuing importance of resource extraction to their economies and growing domestic and global demand for food, energy, and minerals.

Trends of individual developing countries varied widely (figure 6-3):

- Turkey's KTI share had the largest increase among larger developing countries, rising 7 percentage points to reach 23%; most of the increase occurred in commercial KI services.
- Mexico's KTI share gained 5 percentage points to reach 21% due to increases in commercial KI services. Its HT manufacturing share fell from 2% to 1% (appendix tables 6-2–6-4 and 6-7).
- China's KTI share grew by 3 percentage points to reach 20% due entirely to a rise in its HT manufacturing share as it became the primary location for global production of electronic products.
- India's KTI share rose from 16% to 19% due an increase in commercial KI services.

Information and Communications Technology Infrastructure

Many economists regard ICT as a general-purpose platform technology that fundamentally changes how and where economic activity is carried out in today's knowledge-based countries, much as earlier general-purpose technologies (e.g., the steam engine, automatic machinery) propelled growth during the Industrial Revolution.[6] Thus, ICT facilitates broad development of new markets (e.g., for mobile computing, data exchange, and communications) and of new methods, products, organization, and processes. It also raises worker productivity in non-ICT industries.

Because of the shift to knowledge-based production, ICT infrastructure can be as important as or more important than physical infrastructure to raising living standards and remaining economically competitive. A World Bank study of developed and developing countries estimated that a 10 percentage point increase in broadband penetration raises economic growth by 1.2–1.4 percentage points (World Bank 2009:45).

This section examines two broad ICT indicators: an index of ICT infrastructure available to business, consumers, and the public sector; and data on ICT spending by consumers and businesses as a share of GDP. The indexes of ICT infrastructure are composite indicators developed by the *Connectivity Scorecard* that are composed of the following elements:

- The ICT consumer infrastructure measures include data on fixed broadband coverage and penetration, 3G coverage and penetration, wireless telephone penetration, and Internet download speeds.

- The ICT business infrastructure measures include Internet servers and personal computers per capita, ICT investment per capita, and business usage of broadband and mobile data.
- The ICT public sector infrastructure measures include government, health care, and education spending on ICT and a United Nations indicator of online e-government services.[7]

For developing countries, indexes have fewer components due to lack of data availability.

Developed countries. The U.S. ICT infrastructure compares favorably to other large developed countries as measured by these ICT indicators (figure 6-5):

- U.S. businesses invest heavily in and intensively utilize ICT business infrastructure.
- The United States also scores high in public sector infrastructure because of high investment by government, education, and health care sectors in ICT and an extensive number of e-government services.
- The United States scores moderately high in consumer infrastructure. The United States is ahead of Western European countries (except Sweden) in deployment of high-speed broadband but trails Japan and South Korea on this measure.

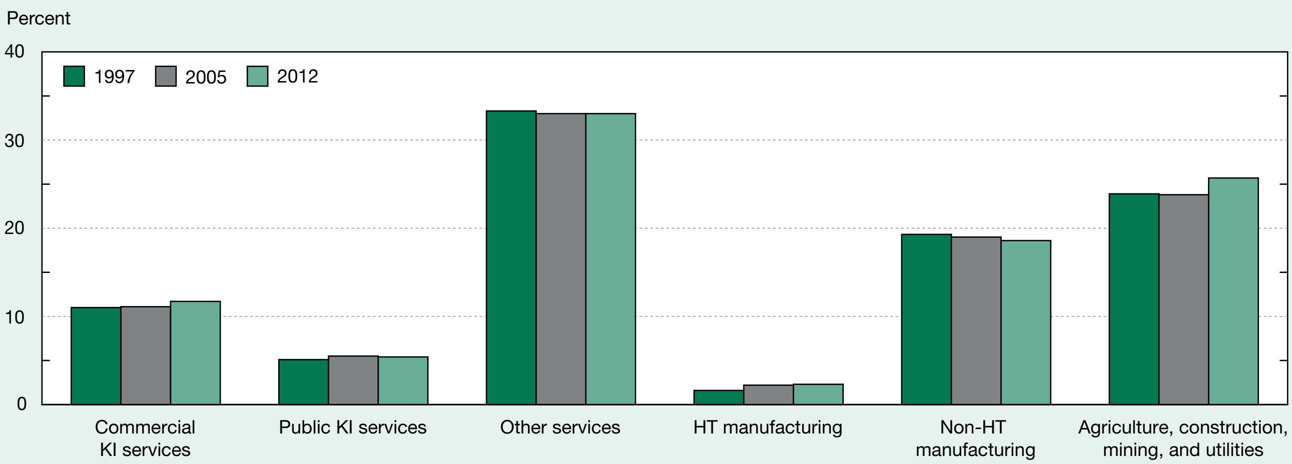
Other countries that have similar scores to the United States are the United Kingdom, Sweden, and Canada (figure 6-5). These countries were early adopters of ICT, and their business sectors are ICT intensive, particularly in the United States and the United Kingdom, which have large sophisticated service industries.

European countries—including France, Germany, and Italy, which were later adopters of ICT—have substantially lower scores in ICT business and public sector infrastructure compared to the United States (figure 6-5). Their business and public sectors are less-intensive users of ICT and invest less in ICT, and their public sectors provide fewer e-government services. Italy and Greece have the weakest index scores among developed countries and, in this respect, are more comparable to developing countries.

South Korea and Japan have the highest scores in consumer infrastructure, which reflects extensive government programs to provide near-universal broadband coverage and 3G networks (figure 6-5). However, these two countries score far weaker in business and public sector ICT infrastructure.

Developing countries. Separate ICT infrastructure indexes for major developing countries show wide variations among them, reflecting in part their level of per capita income (table 6-1; figure 6-6). The three Asian countries—China, India, and Indonesia—have the lowest index scores among the larger developing countries. Indonesia and India have very low scores in the consumer, business, and public sectors because their domestic ICT usage and access for consumers and businesses are limited and uneven, even though India has a high level of ICT service exports and a large pool of skilled ICT workers. China scores somewhat higher on consumer infrastructure, with comparatively higher broadband and fixed-line usage by its populace. China's

Figure 6-4
Selected industry category share of developing economies' GDP: 1997, 2005, and 2012



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries on value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and measuring, testing, and control instruments. Developing economies are classified by the World Bank as higher- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-3–6-7.

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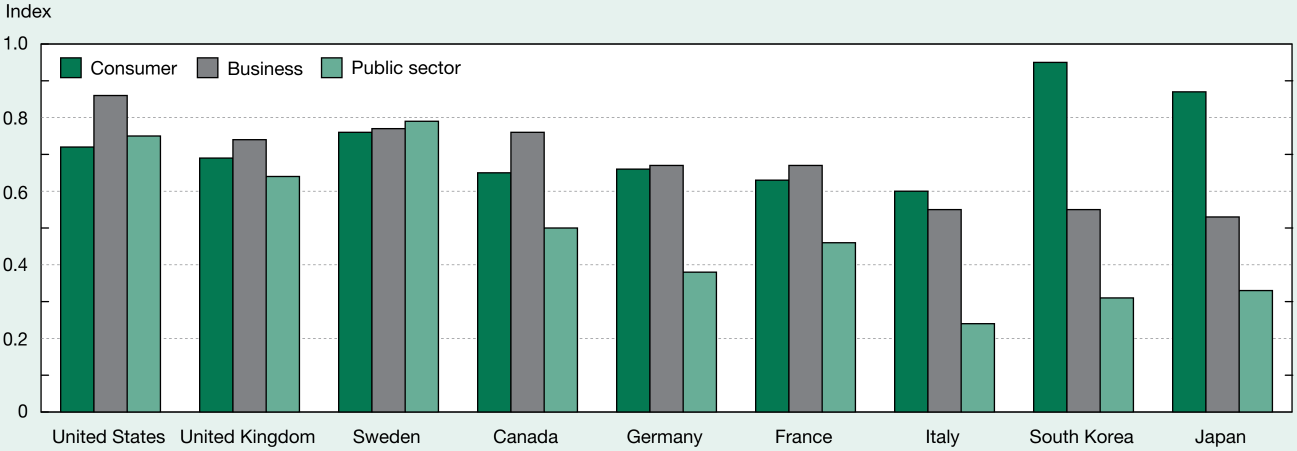
relatively weak score in ICT business infrastructure reflects very low penetration of secure Internet servers and limited international Internet bandwidth.

Developing countries outside of Asia have generally higher index scores, with wide variations (figure 6-6). South Africa has the highest score in public sector infrastructure among developing countries but far weaker scores in business and consumer indexes, which are close to those in the Asian countries. Brazil's and Mexico's scores are comparatively higher in the consumer and public sectors, with somewhat lower scores in business infrastructure, particularly for Mexico. Turkey is strong on consumer infrastructure, moderate on business, and poor in the public sector.

Information and Communications Technology Share of Business and Consumer Spending

Among developed countries, the United States and Canada have the highest ICT spending of businesses and consumers as a share of their GDP (figure 6-7). The next

Figure 6-5
ICT infrastructure indexes of selected developed economies: 2011



ICT = information and communications technology.

NOTES: Scores are based on a variety of data and metrics. For more information on methodology and data sources, see http://www.connectivityscorecard.org/methodology/.

SOURCE: ICT Connectivity Scorecard 2011, http://www.connectivityscorecard.org/, accessed 15 January 2013.

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Table 6-1
ICT infrastructure and per capita income of selected developing economies: 2011 and 2012

Economy	ICT infrastructure index score (2011)			Per capita income (2012)[a]
	Consumer	Business	Public sector	
Russia	0.88	0.47	0.73	18,323
Brazil	0.56	0.46	0.58	14,943
Turkey	0.67	0.55	0.38	13,380
China	0.51	0.22	0.31	10,568
Mexico	0.60	0.36	0.52	10,292
South Africa	0.30	0.44	0.83	9,655
Indonesia	0.41	0.08	0.14	5,408
India	0.22	0.04	0.18	4,431

ICT = information and communications technology.

[a] Per capita income is gross domestic product in 2012 dollars purchasing power parity, divided by population.

NOTES: ICT infrastructure scores are based on a variety of data and metrics. For more information on methodology and data sources, see http://www.connectivityscorecard.org/methodology/.

SOURCES: ICT Connectivity Scorecard 2011, http://www.connectivityscorecard.org/, accessed 15 February 2013; The Conference Board, Total Economy Database on Output and Labor Productivity (January 2013), http://www.conference-board.org/data/productivity.cfm, accessed 15 January 2013. See appendix table 6-10.

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highest are South Korea and the United Kingdom, with 5%, followed by Australia, the EU, and Japan, with 4%.

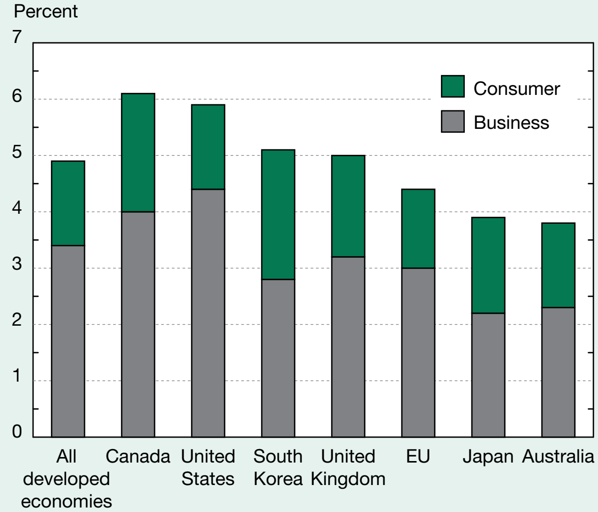
The ICT business spending share is arguably a more important indicator than ICT consumer spending because of the large impact that businesses have on overall economic growth, employment, and productivity. The United States has the highest share of ICT business spending (4.4%), closely followed by Canada (4.0%). The high ICT business spending shares of these two countries coincide with their high scores on ICT business infrastructure (discussed in the previous section). Although scoring as high as the United States and Canada on ICT business infrastructure, the United Kingdom has a lower ICT business spending share of GDP that is nearly the same as the EU average. Japan and Australia have some of the lowest shares in ICT business spending.

Many developing countries have ICT spending shares that are comparable to developed countries (figure 6-8). South Africa, which has the highest share among larger developed countries, matches the levels of Canada and the United States, although South Africa's ICT business spending share is less than that of Canada and the United States. Three countries—Brazil, China, and Turkey—have ICT shares roughly the same as the EU, with similar levels of ICT business spending. India and Indonesia have the lowest ICT spending shares, with their ICT business spending GDP share at 2% or less, coinciding with their low index scores in ICT business infrastructure.

Productivity

Productivity, which is the ratio of production outputs to resource inputs, is considered a key source of economic growth and an indicator of development. The rise in the KTI concentration of economic activity and in business investment in ICT and other knowledge-based assets in many countries has been associated with elevated or rapid productivity growth. This association is evidence that knowledge has become a crucial factor in productivity growth. Business investment in knowledge-based assets—computerized

Figure 6-7
ICT business and consumer spending as a share of GDP for selected developed economies: 2010



EU = European Union; GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2013) from IHS Global Insight ICT Global Navigator.

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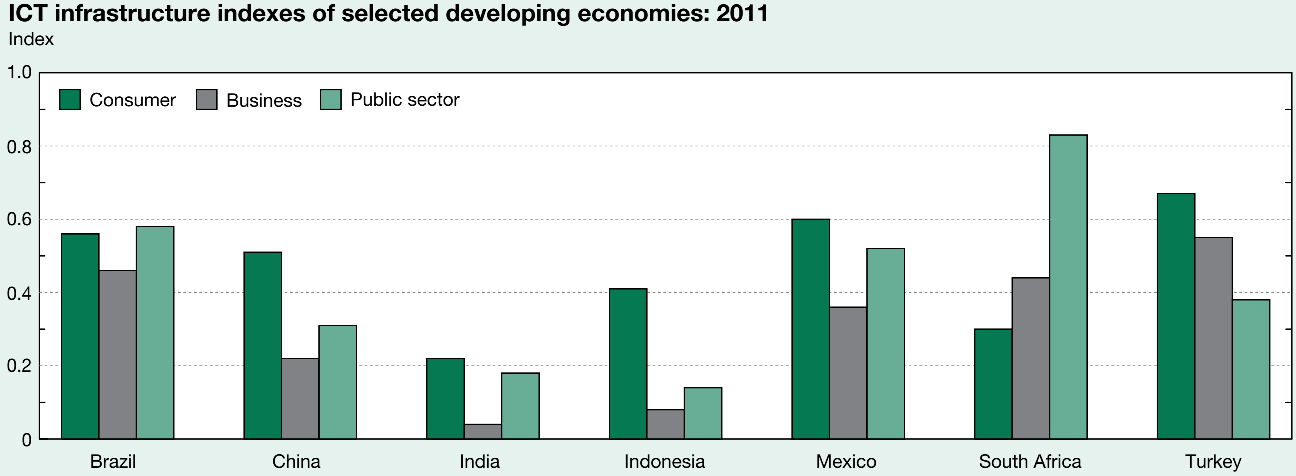
Figure 6-6
ICT infrastructure indexes of selected developing economies: 2011



ICT = information and communications technology.

NOTES: Scores are based on a variety of data and metrics. For more information on methodology and data sources, see http://www.connectivityscorecard.org/methodology/.

SOURCE: ICT Connectivity Scorecard 2011, http://www.connectivityscorecard.org/, accessed 15 January 2013.

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information and software, intellectual property, and economic competencies, including brand equity and training—are estimated to account for 20%–25% of productivity growth in Europe and 27% in the United States between 1995 and 2007 (OECD 2012:2). Because the most accurate measure of productivity, output per hour, is unavailable for many developing countries, GDP per employed person is the proxy measure used here.[8]

After growing at the same pace as developed countries in the late 1990s, labor productivity of developing countries accelerated to reach 6% per annum in the mid-2000s (figure 6-9; appendix table 6-9). The rapid advancement in productivity of developing countries has been attributed to economic liberalization; investment in education, R&D, and physical infrastructure; foreign direct investment and technology transfer by subsidiaries of MNCs; and the migration of workers from agriculture to manufacturing and services. The pace of productivity growth declined in the late 2000s due to cyclical effects of the 2008–09 global recession. Some observers also believe that productivity growth will continue to moderate because China and other fast-growing countries have begun transitioning to a more consumer- and services sector–driven economy, which typically results in lower productivity growth (Conference Board 2013:10).

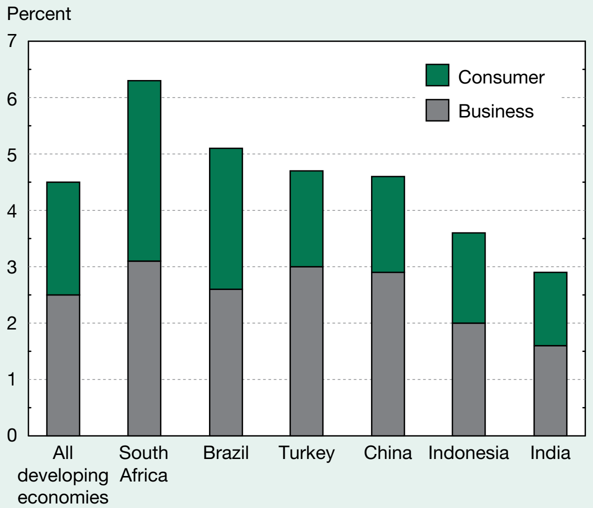
Productivity growth trends among the large developing countries varied widely (figure 6-10; appendix table 6-9):

- China registered the fastest growth of any large developing economy, growing at an average annual rate of nearly 10% between 2003 and 2012, up from 8% between 1997 and 2003.
- India grew the second fastest, increasing at an average annual rate of nearly 6% between 2003 and 2012, up from 4% between 1997 and 2003.
- Three countries—Brazil, Indonesia, and South Africa—had negative growth between 1997 and 2003, followed by modest positive growth between 2003 and 2012. Indonesia had the strongest performance among these countries, with an annual growth rate of 4% between 2003 and 2012. South Africa grew by 3%, with Brazil growing the slowest (1%).

In the developed countries, productivity growth declined from 2% in the early 2000s to negative growth during the 2008–09 recession before rising to about 1% in 2011–12 (figure 6-9; appendix table 6-9). Although the 2008–09 recession was a major factor in the slowdown, productivity growth of developing countries had been slowing prior to the recession. The recovery in productivity growth following the recession has been weak.

Productivity in the United States grew faster than almost all developed countries between 1997 and 2012, with annual average growth of 2.2% between 1997 and 2003 slowing to 1.2% between 2003 and 2012 (figure 6-11; appendix table 6-9). Only South Korea, whose transformation to become a fully developed country is relatively recent, grew faster. Observers and researchers have attributed the United States'

Figure 6-8
ICT business and consumer spending as share of GDP for selected developing economies: 2010



GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2013) from IHS Global Insight ICT Global Navigator.

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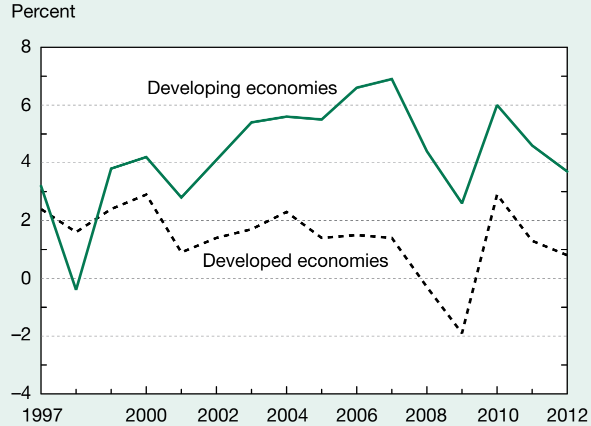
Figure 6-9
Labor productivity growth of developed and developing economies: 1997–2012



GDP = gross domestic product; PPP = purchasing power parity.

NOTES: Labor productivity growth is based on gross domestic product (GDP) per employed person. GDP is in 2012 purchasing power parity (PPP) dollars. Developed countries are those classified by the World Bank as high-income. Developing countries are classified by the World Bank as higher- and lower-middle-income economies and low-income economies.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2013), http://www.conference-board.org/data/productivity.cfm, accessed 15 January 2013. See appendix table 6-9.

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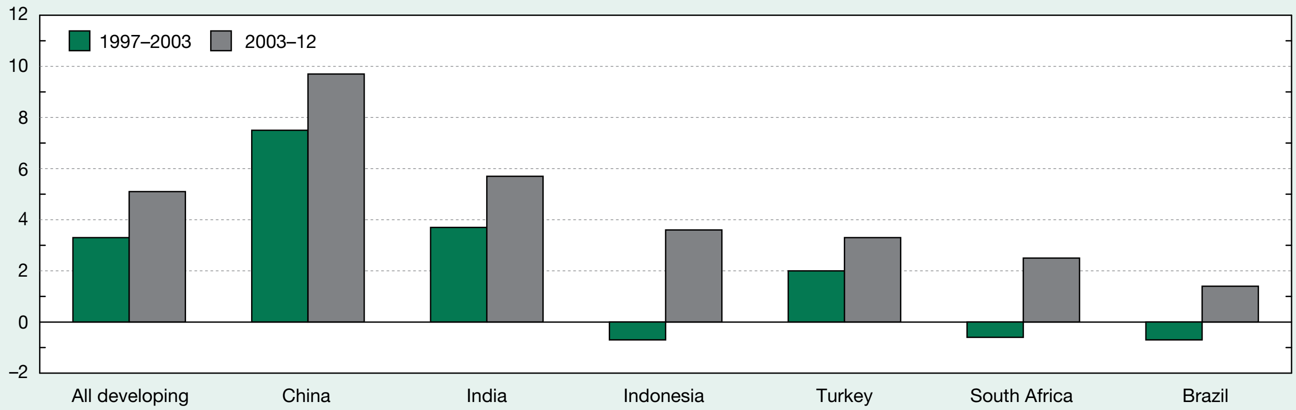
Figure 6-10
Labor productivity growth of selected developing economies: 1997–2012
Percent



NOTES: Labor productivity growth is based on gross domestic product (GDP) per employed person. GDP is in 2012 purchasing power parity (PPP) dollars. China includes Hong Kong. Developing countries are classified by the World Bank as higher- and lower-middle-income economies and low-income economies.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2013), http://www.conference-board.org/data/productivity.cfm, accessed 15 January 2013. See appendix table 6-9.

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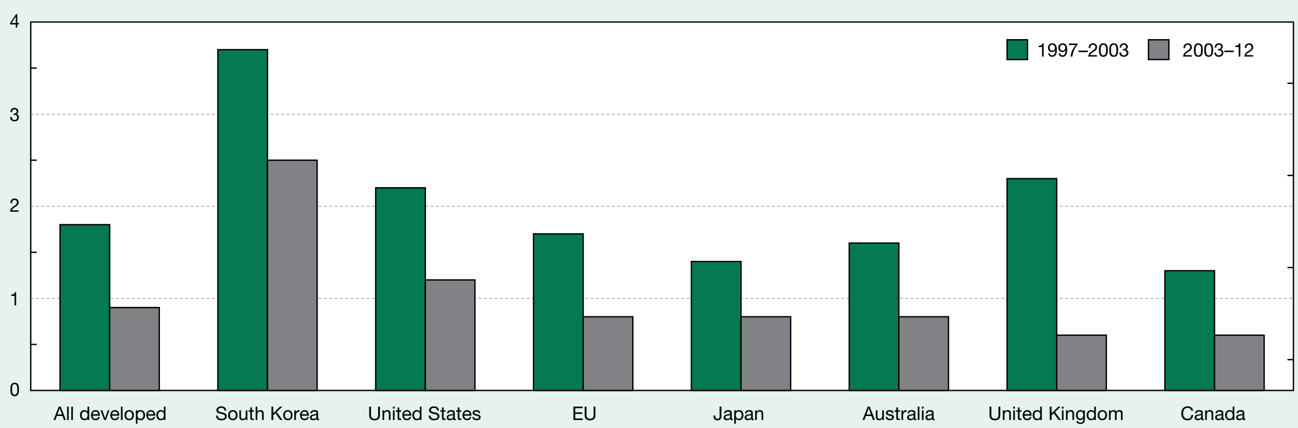
Figure 6-11
Labor productivity growth of selected developed economies: 1997–2012
Percent



EU = European Union.

NOTES: Labor productivity growth is based on gross domestic product (GDP) per employed person. GDP is in 2012 purchasing power parity (PPP) dollars. Developing economies are classified by the World Bank as high-income economies.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2013), http://www.conference-board.org/data/productivity.cfm, accessed 15 January 2013. See appendix table 6-9.

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better performance relative to the EU and Japan to several factors, including faster adoption of ICT technology, more-flexible labor markets, high-quality research universities, and an influx of highly skilled immigrants.

Rapidly rising living standards, expressed as per capita GDP, accompanied the acceleration of productivity growth in developing countries and narrowed their gap with developed countries (figure 6-12; appendix table 6-10). Despite sustained rapid productivity growth by China and several other developing countries, however, their gap with the United States and other developed countries is substantial and is likely to remain for some time, even if China sustains current growth rates. This is because the gap between the levels of per capita GDP in the United States and the developing world is very large. For example, U.S. per capita GDP in 2012 was $49,000 on a purchasing power parity (PPP) basis compared to $10,500 in China, about one-fifth the level of the United States.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

The second section of the chapter examines the changing shares of global activity in KTI industries attributed to the United States and other major economies (appendix table 6-1). (For an explanation of KTI industries, please see "Chapter Overview.") As national and regional economies change, the worldwide centers of KTI industries shift in importance. Shifts take place for this entire group of industries and for individual service and manufacturing industries within the group. This section examines the positions of the United States and other major economies in KTI industries.

Health and Education Services

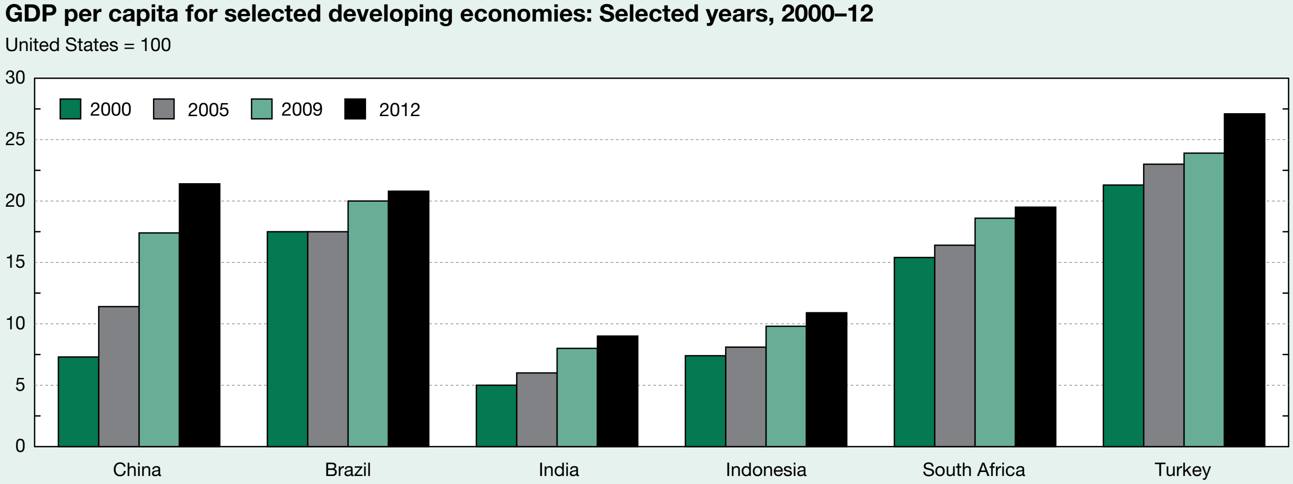
Although health and education services are not as fully competitive or globally integrated as other KTI industries, these sectors are major sources of knowledge and innovation that benefit the entire economy. Education trains students for future work in science, technology, and other knowledge fields, and research universities are an important source of knowledge and innovation for other economic sectors.

International comparison of the health and education sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

The United States and the EU are the world's largest providers of education services, with world shares of 27%–30% (appendix tables 6-3 and 6-5). China is the third-largest provider, followed by Japan. Country and regional shares are similar in health care, except that Japan places ahead of China (appendix table 6-6).

The U.S. and EU global shares of education and health care fell modestly between 2003 and 2012 (appendix tables 6-3, 6-5, and 6-6). Japan's share fell more sharply. China's global share of education and health care services at least doubled during this period, in line with its rapid economic growth. Brazil, India, and Indonesia showed a similar expansion in their global shares. The growth of education in China

Figure 6-12
GDP per capita for selected developing economies: Selected years, 2000–12



GDP = gross domestic product.

NOTES: GDP per capita income is expressed as an index where 100 equals the per capita income of the United States. GDP per capita income is in 2012 purchasing power parity (PPP) dollars. China includes Hong Kong.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2013), http://www.conference-board.org/data/productivity.cfm, accessed 15 January 2013. See appendix table 6-10.

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and India coincided with increases in both of these countries in earned doctorates in the natural S&E fields (see chapter 2).

Commercial Knowledge-Intensive Service Industries

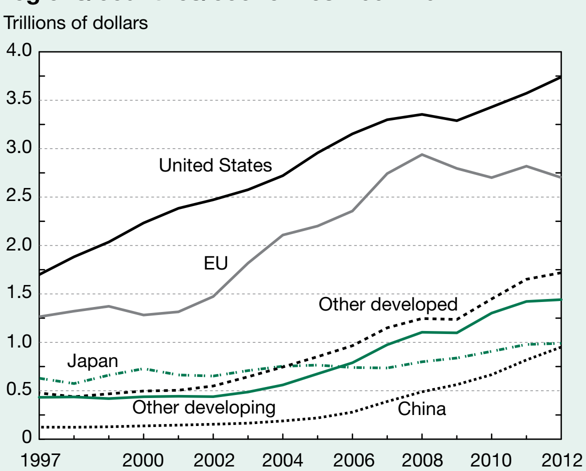
The global value added of commercial KI services—business, financial, and telecommunications—was $11.5 trillion in 2012 (figure 6-13; appendix table 6-4). Business services, which includes the technologically advanced industries of computer programming and R&D services, is the largest service industry ($5.6 trillion), closely followed by financial services ($4.3 trillion), with telecommunications far smaller ($1.6 trillion) (appendix tables 6-8, 6-11, and 6-12).

Patterns and Trends in Developing Countries

Developing countries comprise about one-fifth of global value added of commercial KI services industries (figure 6-13; appendix table 6-4). China (8% global share) is the largest provider among developing countries and essentially ties with Japan as the third-largest global provider. Other large developing countries have global shares of 2% or less.

From 1997 to 2003, the value added of commercial KI services grew at roughly the same rate in developed and developing countries (figure 6-13; appendix table 6-4). Starting in 2003, growth accelerated in developing countries, resulting in their share of global output doubling from 10% to 21% in 2012.

Figure 6-13
Output of commercial KI services for selected regions/countries/economies: 1997–2012



EU = European Union; KI = knowledge intensive.

NOTES: Output of knowledge- and technology-intensive industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed economies are classified by the World Bank as high income. Developing economies are classified by the World Bank as upper- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix table 6-4.

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China grew the fastest among developing countries and accounted for 45% of the expansion of all developing countries between 2003 and 2012 (appendix table 6-4). China's world share more than doubled to reach 8% to tie with Japan as the third-largest provider (figure 6-13). Among the commercial KI services, China had the largest gain in financial services, which may reflect the substantial role of public-owned or public-supported financial institutions and development banks in that country.

Brazil and India also had sizeable gains in commercial KI services, with each reaching global shares of 2% (appendix table 6-4). Brazil's expansion was led by financial services and telecommunications (appendix tables 6-8 and 6-12). India gained the most in business services, particularly in computer programming, reflecting, in part, the success of firms providing information technology (IT), accounting, legal, and other services to developed countries (appendix tables 6-11 and 6-13). Indonesia, which has a smaller global share than these two countries, grew the second fastest among the larger developing countries (see sidebar, "Indonesia's Rapid Growth in Commercial Knowledge-Intensive Services").

Patterns and Trends in Developed Countries

Commercial KI services industries in developed economies comprise four-fifths of global value added (figure 6-13; appendix table 6-4). The United States has the largest commercial KI services industries, with a 32% share of global value added. U.S. commercial KI services industries employ 18 million workers, 14% of the U.S. labor force, and pay higher-than-average wages (table 6-2; figure 6-14). In addition, these industries have a much higher concentration of skilled workers as measured by the proportion of those in S&E occupations. These industries fund roughly one-fourth of U.S. industry R&D.

The EU is the second-largest global provider of commercial KI services, with a 23% global share, followed by Japan (9%), which is essentially tied with China (figure 6-13).

After growing rapidly between 2003 and 2008, the valued added of commercial KI services of developed economies contracted in 2009 before rebounding in 2010–12 (figure 6-13; appendix table 6-4). However, growth in developed economies lagged developing economies, primarily due to China's rapid expansion. As a result, the global share of developed countries fell from 90% in 2003 to 79% in 2012.

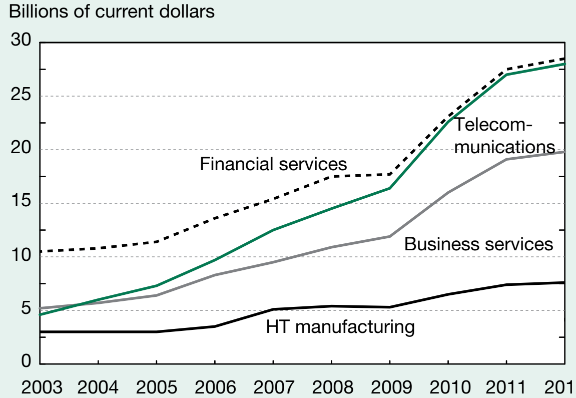
After expanding rapidly prior to the global recession, value added of U.S. commercial KI services dipped in 2009 before rebounding to reach $3.7 trillion in 2012, 12% higher than its level prior to the global recession (figure 6-13; appendix table 6-4). Between 2003 and 2012, the U.S. global share slid from 40% to plateau at 32% beginning in 2011. Employment in U.S. commercial KI services has had a weaker recovery (figure 6-14). Commercial KI services lost 1.0 million jobs during the recession. Although jobs grew modestly in 2011–12, employment in 2012 remains 300,000 jobs below its pre-recession level.

The United States is the leading global provider of business services, which led the growth of U.S. commercial KI industries

Indonesia's Rapid Growth in Commercial Knowledge-Intensive Services

Indonesia's commercial knowledge-intensive services more than doubled between 2007 and 2012, expanding 40% faster than the average for all developing countries (figure 6-A). Among the three individual industries, telecommunications grew the fastest, closely followed by business services. Indonesia's high-technology manufacturing industries also grew rapidly, with their value-added output more than doubling between 2003 and 2012. Indonesia's economy has benefitted from a sharp reduction in its budget deficit and from government programs to improve education, health care, and technological development. Unlike many of its more export-dependent neighbors, Indonesia has managed to skirt the recession, helped by strong domestic demand (which makes up about two-thirds of the economy) and a government fiscal stimulus package of about 1.4% of GDP. In addition, the government has implemented various programs to expand and improve education and health care and to increase technological development.

Figure 6-A
Indonesia's commercial KI services and HT manufacturing industries: 2003–12



HT = high technology; KI = knowledge intensive.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services consist of business, financial, and communication services. Business services include computer programming, R&D, and other business services. Financial service includes leasing. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and consist of aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-8 and 6-11–6-13.

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Table 6-2
Employment and R&D for selected U.S. industries: 2012 or most recent year

Industry	Employment (millions of persons)	S&E share	Average salary (actual $)	Business R&D (2009) ($ billions)
All industries	133.7	4.4	45,000	282.4
Commercial KI services	18.4	15.8	68,000	78.8
HT manufacturing	1.8	26.4	70,000	135.9

HT = high technology; KI = knowledge intensive.

NOTES: Business R&D consists of domestic funding by companies' own internal funds and funds from other sources. Employment consists of the nonagricultural workforce. HT manufacturing industries and KI services are classified by the Organisation for Economic Co-operation and Development. HT manufacturing includes computers, communications, semiconductors, electronic and measuring instruments, aircraft and space vehicles, and pharmaceuticals. KI services include health, education, business, information, and financial services. Commercial KI services include business, information, and financial services. Business R&D of commercial KI services consists of professional and technical services and information. Coverage of some industries may vary among data sources due to differences in classification of industries. Salaries are rounded to the nearest thousand.

SOURCES: Bureau of Economic Analysis, Annual Industry Accounts, http://www.bea.gov/industry/index.htm#annual; Bureau of Labor Statistics, Current Employment Survey, http://www.bls.gov/ces/; Bureau of Labor Statistics, Occupational Employment Survey, special tabulations; National Science Foundation, National Center for Science and Engineering Statistics, Business Research and Development and Innovation Survey, http://www.nsf.gov/statistics/srvyindustry/.

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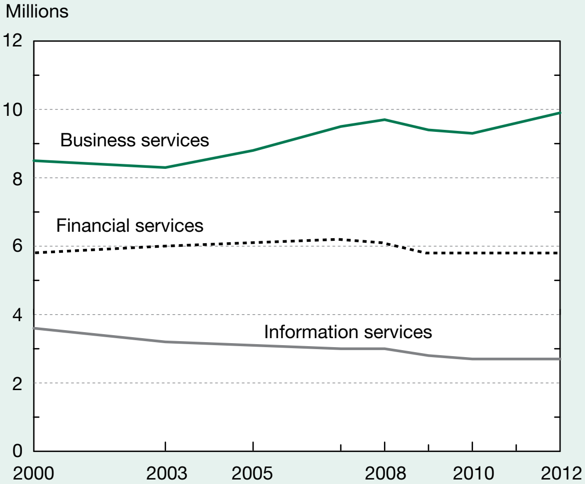
Figure 6-14
U.S. employment in commercial KI services: Selected years, 2000–12



KI = knowledge intensive.

NOTES: KI services are classified by the Organisation for Economic Co-operation and Development. Commercial KI services include business, information, and financial services.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (August 2013), http://www.bls.gov/ces/, accessed 8 August 2013.

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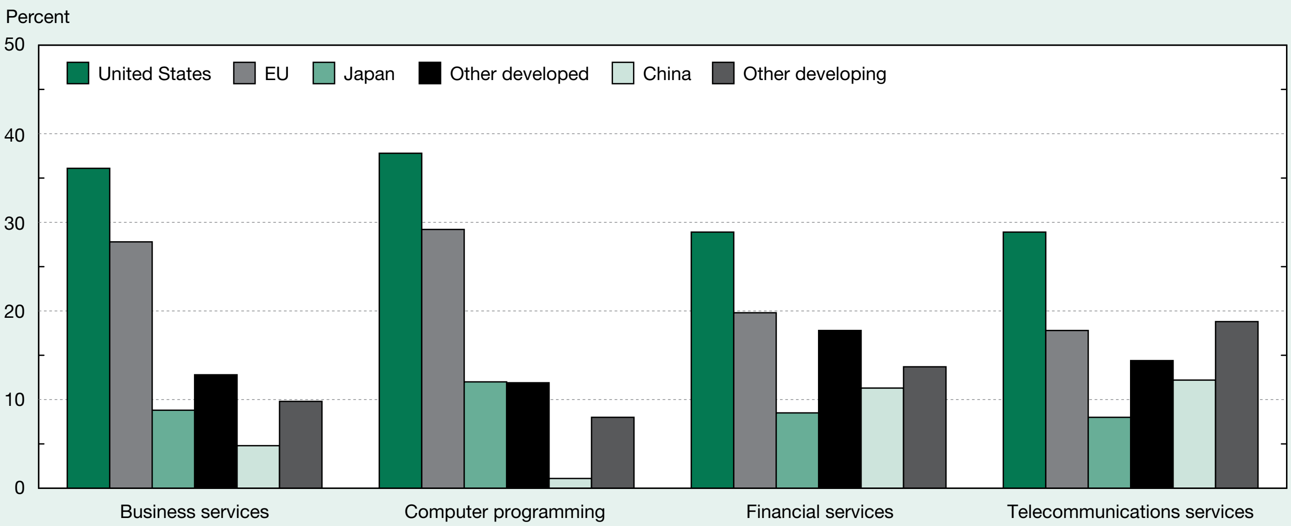
between 2003 and 2012 (figure 6-15; appendix table 6-11). Value added of business services grew slightly faster than all commercial KI industries (55% versus 45%), with value added of computer programming expanding 66% (appendix table 6-13). One source of growth of U.S. business services has been the infrastructure boom in developing countries that have employed U.S. firms in areas including architecture, engineering, and consulting.[9] U.S. employment in business services grew from 8.3 million in 2003 to reach 9.9 million in 2012, 400,000 jobs greater than the pre-recession level (figure 6-14).

The EU, which is the second-largest global provider, has fared worse than the United States since the recession. In the midst of the EU's financial and economic difficulties, the value added of its commercial KI services has remained stagnant in 2009–12 and below its pre-recession peak (figure 6-13; appendix table 6-4). As a result, the EU's global share dropped from 30% in 2008 to 23% 2012.

In the aftermath of the recession, Japan has performed better than the United States or the EU in this industry group. Value-added output continued to expand during and following the recession to reach a level nearly 25% higher than the pre-recession peak (figure 6-13; appendix table 6-4). Japan's share fell slightly, from 11% in 2003 to 9% in 2006, where it has remained steady. However, the substantial appreciation of the Japanese yen relative to the dollar during this period may have overstated the strength of Japan's commercial KI services industries (see sidebar, "Currency Exchange Rates of Major Economies").

Figure 6-15
Global value-added shares of selected regions/countries/economies for selected service industries: 2012



EU = European Union.

NOTES: Output on a value-added basis is shown above bars in trillions of dollars. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Business services include computer programming, R&D, and other business services. Data on computer programming, a componenet of business services, is provided separately. Financial services include leasing. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are classifed as high-income countries by the World Bank. Developing countries are classified by the World Bank as upper- and lower-middle-income countries and low-income countries.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-11–6-13.

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Currency Exchange Rates of Major Economies

International comparisons of industry, trade, investment, and other global economic activities often use current dollars at market exchange rates. Most global economic activities are dollar denominated, which facilitates comparison. In addition, many economists believe that market exchange rates reflect, at least to some degree, differences in economic performance among various countries (Balke, Ma, and Wohar 2013:2).

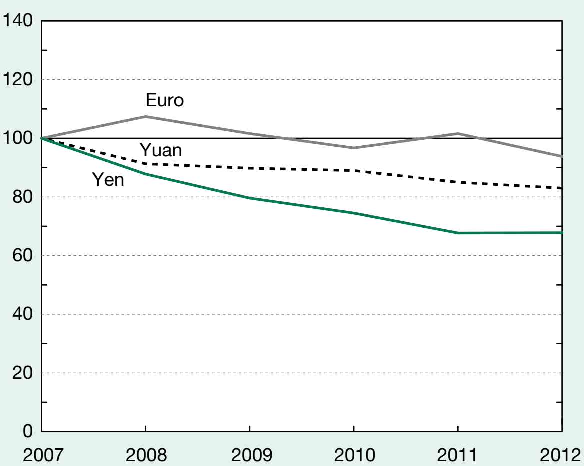
However, fluctuations in exchange rates may reflect factors other than economic performance. Governments can and do take action to influence the level of their exchange rates, ranging from intervening in currency exchange markets so as to exercise almost complete control of rates to using macroeconomic policies and other mechanisms so as to exercise more limited and indirect influence on markets. In addition, factors such as political instability or the short-term effects of global financial events on a country's economy can cause currency fluctuations that are unrelated to enduring differences in national economic performance. Factors such as these mean that comparing economic data from different countries in current dollar terms can sometimes provide an inaccurate and misleading measure of a country's relative economic performance.

Between 2007 and 2012, during the global financial crisis, the worldwide recession, and the subsequent economic recovery, the exchange rates of the four largest economies—China, the EU member countries that use the euro (the Eurozone), Japan, and the United States—exhibited considerable fluctuations (figure 6-B). The Japanese yen showed the largest change among these currencies, with an appreciation of 30% against the U.S. dollar to a nearly post–World War II high. Some experts attributed the strong appreciation of the yen to its attractiveness as a safe haven in response to Europe's debt problems and doubts about U.S. economic growth (Tabuchi 2011). The yuan's exchange rate, which is controlled by China's government, also appreciated against the dollar, although at a more modest pace.

The substantial appreciation of the yen and yuan against the dollar from 2007 to 2012 made Japan's and China's positions in economic activities denominated in current U.S. dollars appear progressively stronger during this period. Denominated in local currency terms, however, their economic performance looked weaker. The disparity was particularly large for Japan. For example, the value added of Japan's high-technology manufacturing industries in current dollars exhibited a slight decline (4%) from 2007 to 2012 (figure 6-C). The value added in yen shows a much deeper decline (35%).

Figure 6-B
U.S. dollar exchange rate with selected currencies: 2007–12

2007 = 100



SOURCE: Federal Reserve, Economic and Research and Data, Foreign Exchange Rates, http://www.federalreserve.gov/releases/h10/current/, accessed 15 May 2013.

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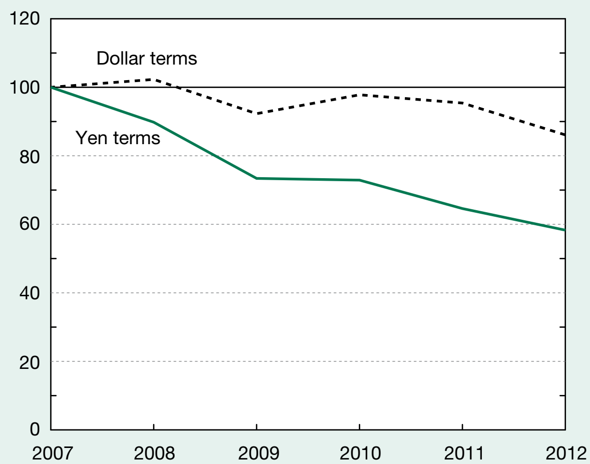
Figure 6-C
Output of Japan's HT manufacturing industries: 2007–12

2007 = 100



HT = high technology.

NOTES: Output of HT manufacturing industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments. See appendix table 6-7.

SOURCES: Federal Reserve, Economic Research and Data, Foreign Exchange Rates http://www.federalreserve.gov/releases/h10/current/, accessed 15 May 2013; IHS Global Insight, World Industry Service database (2013).

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Australia had the fastest growth in commercial KI services among large developing economies during this period (appendix table 6-4). Its global share doubled from 1.7% in 2003 to 3.7% in 2012. Australia's rapid expansion is due in part to its growing economic integration with China (see sidebar, "Australia's Commercial Knowledge-Intensive Services Grow Strongly").

High-Technology Manufacturing Industries

Global value added of HT manufacturing was $1.5 trillion in 2012, making up 14% of the manufacturing sector (figure 6-16; appendix tables 6-7 and 6-14). The three ICT manufacturing industries—communications, computers, and semiconductors—make up a collective $0.6 trillion in global value added (appendix tables 6-15–6-17). The three remaining industries are scientific instruments and pharmaceuticals, each with about $350 billion in value added, and aircraft and spacecraft, with $180 billion (appendix tables 6-18–6-20).

Patterns and Trends in Developing Countries

China is the second-largest global producer of HT products (24% global share) (figure 6-16; appendix table 6-7). These HT products are largely exported to the rest of the world. Most of China's production is performed in plants controlled by MNCs using imported inputs and components. Other large developing countries have global shares of 2% or less.

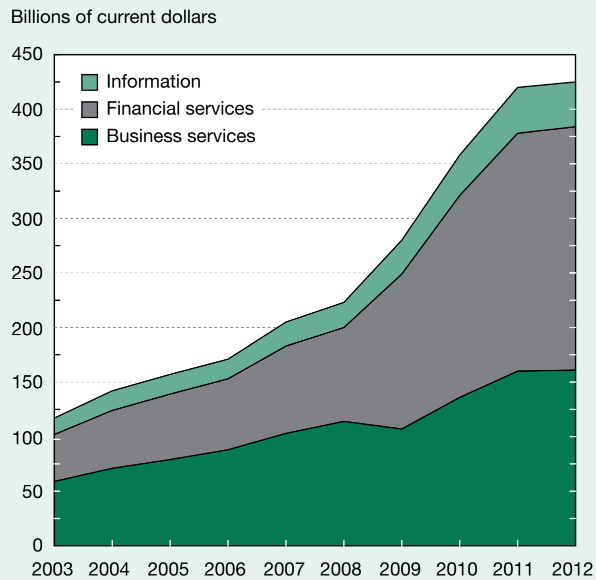
Growth of HT manufacturing in developing countries sharply accelerated starting in 2003 almost entirely due to China's rapid expansion (figure 6-16; appendix table 6-7). Between 2003 and 2012, China's value added rose more than fivefold, resulting in its global share climbing from 8% in 2003 to 24% in 2012. China's output fell slightly in 2009 during the 2008–09 recession, at a time when output declined more substantially in most other developing and developed countries. Among the HT industries, China made the most rapid gain in ICT manufacturing industries, with its global share reaching 36% in 2012 (figure 6-17; appendix tables 6-15–6-17). China also made huge gains in pharmaceuticals, reaching a global share of 25% in 2012 to tie with the EU as the world's largest producer (appendix table 6-18). Production of generic drugs by Chinese-based firms and the establishment of production facilities controlled by U.S. and EU multinationals were major factors in this industry's rapid expansion.

Despite some progress in producing globally competitive HT goods, notably in telecommunications equipment, Chinese HT manufacturing companies largely continue to be limited to lower-value activities, such as final assembly.[10] For example, within the semiconductor industry, Chinese firms have a limited share (20%) of China's rapidly growing market for integrated circuits, which foreign firms continue to dominate (PwC 2012). In addition, Chinese HT companies have not met many of the ambitious targets and goals of the Chinese government's indigenous innovation program.

Australia's Commercial Knowledge-Intensive Services Grow Strongly

Australia's commercial KI services grew four times faster than the average of all developed countries between 2003 and 2012 (figure 6-D; appendix table 6-4). The financial sector grew the fastest among the commercial KI services, with telecommunications and business services growing considerably slower. Australia's high-technology manufacturing industries also grew significantly faster than the developed country average, largely because of rapid growth in its pharmaceuticals industry. Australia's economy has had two decades of uninterrupted growth and was one of the few developed economies to escape the global recession. A primary factor in its growth has been booming demand by China and other Asian countries for its iron ore and other mining commodities. Its dependence on commodity exports has prompted the government to develop policies to make its economic growth more broad based.

Figure 6-D
Australia's commercial KI services industries: 2003–12



KI = knowledge intensive.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services consist of business, financial, and communications services.See appendix tables 6-8, 6-11, and 6-12.

SOURCE: IHS Global Insight, World Industry Service database (2013).

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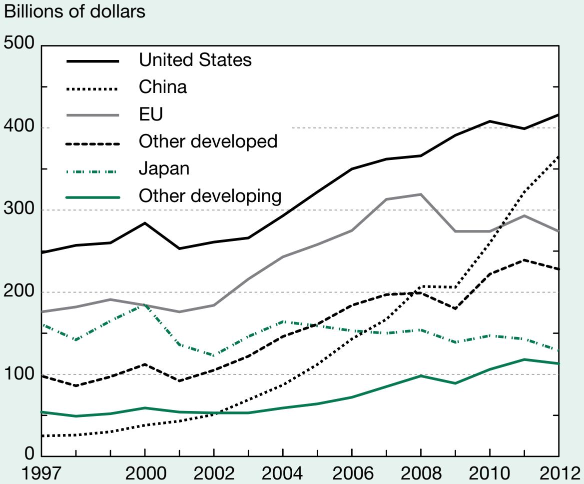
Figure 6-16
Output of HT manufacturing industries for selected regions/countries/economies: 1997–2012



EU = European Union; HT = high technology.

NOTES: Output of HT manufacturing industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries classified as high-income countries by the World Bank. Developing countries classified as upper- and lower-middle-income countries and low-income countries by the World Bank.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix table 6-7.

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Anecdotal reports suggest that some multinationals are relocating their facilities from China to other developing countries with lower labor costs or reshoring production in developed countries in response to increases in transportation costs and in China's manufacturing wages.[11] China's growth in ICT manufacturing industries appears to have slowed during the 2000s even prior to the global recession, although the slowdown may reflect the limitations of further expanding China's huge capacity (figure 6-18; appendix tables 6-15–6-17). However, China remains an attractive location for foreign MNCs because of its well-developed and globally capable manufacturing infrastructure. In addition, China's growing and potentially huge domestic market is prompting some foreign HT firms to expand their production facilities and establish R&D laboratories to develop products for China's rapidly growing consumer market.

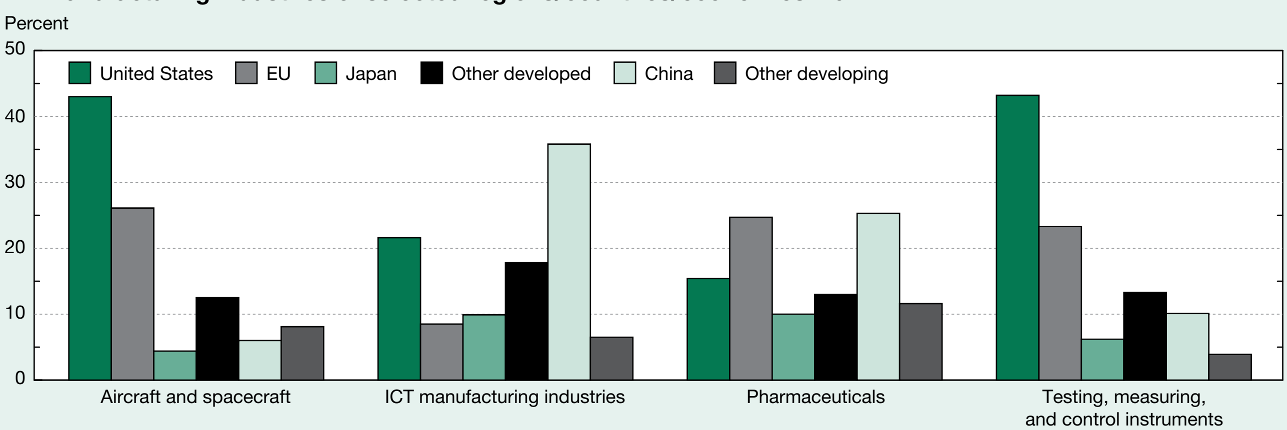
Other large developing countries that grew rapidly included Brazil and India (see sidebar, "Brazil's and India's High-Technology Manufacturing Industries").

Patterns and Trends in Developed Countries

Developed countries make up 66% of global value added of HT manufacturing industries (appendix table 6-7). The United States, which has a 27% global share, is the largest global producer (figure 6-16). U.S. HT manufacturing industries employ 1.8 million workers, 16% of the manufacturing labor force, and pay higher-than-average wages due, in part, to their high concentration of highly skilled S&E workers (table 6-2). Although a small part of the U.S economy, U.S. HT manufacturing industries fund about one-half of U.S. business R&D.

The EU and Japan are the third- and fourth-largest global producers with shares of 18% and 8%, respectively (figure 6-16; appendix table 6-7). Several Asian economies are both

Figure 6-17
HT manufacturing industries of selected regions/countries/economies: 2012



EU = European Union; HT = high technology; ICT = information and communications technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments. ICT manufacturing industries consist of computers, communications, and semiconductors. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries classified as high-income countries by the World Bank. Developing countries classified as upper- and lower-middle-income countries and low-income countries by the World Bank.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-21 and 6-25–6-31.

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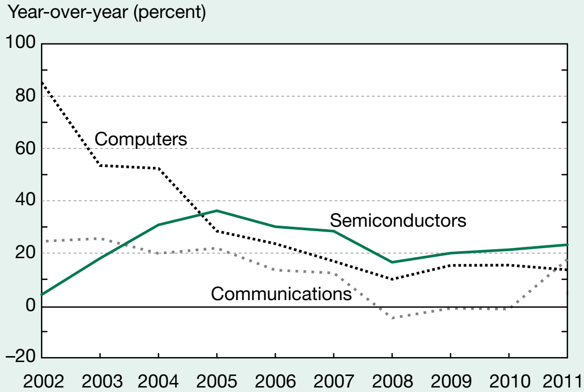
Figure 6-18
Output of China's ICT manufacturing industries: 2002–11



ICT = information and communications technology.

NOTES: Growth is on a 3-year moving-average basis of the value added of ICT manufacturing industries. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. ICT manufacturing industries consist of communications, computers, and semiconductors. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-15–6-17.

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major domestic producers and suppliers of inputs and components to China. The largest—Singapore, South Korea, and Taiwan—have a collective share of 8%.

After expanding briskly prior to the recession, the value added by HT manufacturing industries of developed countries contracted by 5% in 2008, a far larger decline than in developed countries' commercial KI services (figure 6-16; appendix table 6-7). The recovery of HT manufacturing industries following the global recession was modest. Between 2003 and 2012, the global share of developed countries fell steadily from 86% in 2003 to 69% in 2012, due entirely to a collective 18 percentage point decline in the global shares of the United States, the EU, and Japan.

In the United States, value added dipped slightly in 2008 during the recession before rebounding strongly to reach 14% higher than its pre-recession level (figure 6-16; appendix table 6-7). After falling from 33% in the early 2000s to 27% in 2008, the U.S. global share has remained roughly steady in 2009–12.

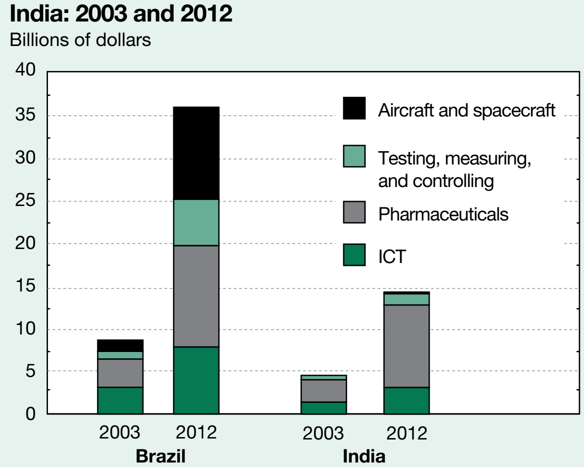
U.S. employment has fared worse prior to and following the recession. HT manufacturing jobs fell from 2.5 million in 2000 to 2.0 million in 2008 before shedding 200,000 more jobs during the global recession (figure 6-19). Furthermore, HT manufacturing employment has remained stagnant following the recession. The steady loss of employment reflects the relocation of production to China and other countries and

Brazil's and India's High-Technology Manufacturing Industries

Brazil's high-technology (HT) manufacturing industries grew more than twice as fast as the average for all developing countries, excluding China, between 2003 and 2012. Pharmaceuticals and aircraft and spacecraft led the growth of Brazil's HT industries (figure 6-E). The expansion of Brazil's pharmaceuticals industry has been boosted by the establishment of manufacturing plants by foreign multinationals to capitalize on Brazil's growing consumer market. Brazil is a major global producer of aircraft and has invested heavily in R&D for spacecraft and satellites. Growth was also rapid in scientific instruments.

India's pharmaceuticals industry, a globally competitive industry, has led the growth of its HT manufacturing industries, which quadrupled in value added between 2003 and 2012 (figure 6-E). India's pharmaceuticals industry is a major global manufacturer of generic drugs and, more recently, has been conducting clinical trials and manufacturing drugs for Western pharmaceutical companies. India, which has been weak in manufacture of electronics, has also had significant growth in its three information and communications technology (ICT) manufacturing industries. Most production of ICT manufacturing has been low value-added assembly in plants controlled by foreign multinational companies; however, the government has recently released its strategy for strengthening its electronic manufacturing industry.

Figure 6-E
Selected manufacturing industries of Brazil and India: 2003 and 2012



ICT = information and communications technologies.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. ICT manufacturing industries consist of communications, computers, and semiconductors. See appendix tables 6-15–6-20.

SOURCE: IHS Global Insight, World Industry Service database (2013).

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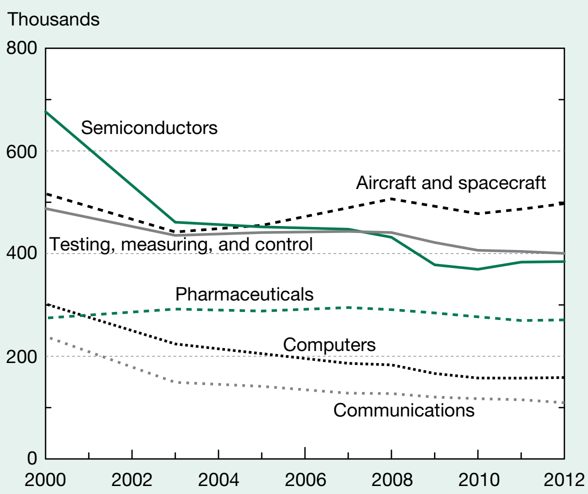
also the rapid productivity growth of U.S. HT manufacturing industries, which have eliminated some jobs, particularly those in routine tasks (see sidebar, "U.S. Manufacturing and Employment"). Researchers and policymakers have concluded that the location of HT manufacturing and R&D activities may lead to the migration of higher-value activities abroad (Fuchs and Kirchain 2010:2344).

Trends among individual U.S. industries were variable:

- Testing, measuring, and control instruments led growth of U.S. HT manufacturing industries due to increased demand for these products for a variety of purposes, including meeting environmental standards (appendix table 6-19). However, employment declined from 490,000 jobs in 2000 to 400,000 jobs in 2012 (figure 6-19).
- The United States is also the largest producer in aircraft and spacecraft, reflecting its historical dominance and the U.S. government's procurement of military aircraft and spacecraft (figure 6-17; appendix table 6-20). Employment remained flat in this industry at about 500,000 jobs (figure 6-19).
- Value-added output in ICT industries contracted, reflecting the relocation of production abroad and labor saving from rapid productivity growth (appendix tables 6-15–6-17). Employment dropped from 1.2 million in 2000 to 650,000 in 2012 (figure 6-19).

Figure 6-19
U.S. employment in HT manufacturing industries: 2000–12



HT = high technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development. HT manufacturing industries include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (August 2013), http://www.bls.gov/ces/, accessed 8 August 2013.

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U.S. Manufacturing and Employment

Several signs point to an increase in U.S. manufacturing activity after years of decline. After falling continuously in the previous decade, employment in the U.S. manufacturing sector increased somewhat in 2011–12, coinciding with a rebound in this sector's output following the 2008–09 global recession.* According to press reports, several firms, including Apple, GE, and Lenovo, are building new manufacturing facilities in the United States (Booth 2013:1). Furthermore, some analysts and researchers predict a resurgence in U.S. manufacturing production, pointing to low transportation and energy costs, modest U.S. labor costs, and favorable currency exchange rates as factors conducive to manufacturing growth (PwC 2012:3).

However, other observers doubt that large-scale increases in employment will accompany increased U.S. manufacturing production. Many U.S. manufacturing industries are highly productive, which allows them to increase output substantially without increasing employment much. Although manufacturers in the United States and other high-income economies will continue to hire more high-skilled workers, manufacturing employment is likely to continue to decline over the next several decades due to further advances in productivity and global competitive pressures (McKinsey Global Institute 2012:4).

In interpreting recent trends in manufacturing production and employment, it is helpful to take into account several broader trends and patterns:

- The share of manufacturing production and employment has steadily declined in the United States and other advanced countries over the past several decades (Shipp et al. 2012:61).
- In wealthy countries, manufacturing continues to play a key role in innovation, productivity, and exports, even as its share of output and employment declines.
- As a share of a country's economy, manufacturing production and employment peak when a country's per capita income reaches a middle level (McKinsey Global Institute 2012:3). At higher per capita income levels, output and employment grow more rapidly in the service sector than in manufacturing.

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* Employment in the U.S. manufacturing sector increased by about 200,000 jobs in both 2011 and 2012, according to the U.S. Bureau of Labor Statistics' Current Employment Survey, http://www.bls.gov/ces/data.htm, accessed 10 June 2013.

- Pharmaceuticals showed little growth during this period (appendix table 6-18). The expiration of patents on highly profitable blockbuster drugs, the lack of new breakthrough drugs, increasing competition from generic drugs, and the relocation of production to other countries were among the factors accounting for tepid growth.

Other major Asian producers—Singapore, South Korea, and Taiwan—showed little change in their global shares during this period. After rapid expansion in HT manufacturing in the prior two decades, companies based in these economies have relocated some of their production facilities to China and other low-cost locations. For example, many Taiwanese ICT firms have shifted their production to mainland China.

Trade and Other Globalization Indicators

The third section of this chapter examines several trade and globalization measures associated with KTI industries in the United States and other economies. (For an explanation of KTI industries, please see "Chapter Overview.") In the modern world economy, production is more often *globalized* (i.e., value is added to a product or service in more than one nation) and less often *vertically integrated* (i.e., conducted under the auspices of a single company and its subsidiaries) than in the past. These trends have affected all industries, but their impact has been pronounced in many commercial KTI industries. The broader context is the rapid expansion of these industrial and service capabilities in many developing countries, both for export and internal consumption, accompanied by an increasing supply of skilled, internationally mobile workers. (See chapter 3 for a discussion on the migration of highly skilled labor.)

This section focuses on cross-border trade of international KI services and HT trade and on U.S. trade of ATP. (See "U.S. Trade in Advanced Technology Products" later in this chapter for a discussion of how the U.S. Census Bureau's classification of ATP differs from the classification of HT products based on the OECD industry classification.) It will also examine trade and other globalization measures of U.S. multinationals in KTI industries. Trade data are a useful although imperfect indicator of globalization (for a discussion, see sidebar, "Measurement and Limitations of Trade Data").

This discussion of trade trends in KI services and HT manufactured products focuses on (1) the trading zones of the North American Free Trade Agreement (NAFTA), with a particular focus on the United States, and the EU; (2) China, which is rapidly taking on an increasingly important role in KTI trade; (3) Japan and other Asian countries; and (4) large developing countries, including Brazil, India, and Indonesia.

The EU, East Asia, and NAFTA have substantial volumes of intraregional trade. This section treats trade within these three regions in different ways. Intra-EU and NAFTA exports are not counted because they are integrated trading zones with common external trade tariffs and few restrictions on intraregional trade. This kind of trade is treated as essentially equivalent to trade between China and Hong Kong, which is excluded because it is essentially intraeconomy trade. (Data on trade in commercial KI services between China and Hong Kong are not available.) Intra-Asian trade is counted for other Asian countries because they have a far smaller degree of trade integration.

Measurement and Limitations of Trade Data

Trade data are based on a classification of goods or services themselves. In the case of product trade, trade is assigned one product code according to the Harmonized Commodity Description and Coding System, or Harmonized System (HS).* The product classification of trade is fundamentally different from the industry classification used in the last section, which is based on the primary activity of the industry that produced a product and not on the characteristics of the product itself. Thus, the two classifications cannot be mapped onto each other. For example, an export classified as a computer service in the product-based system may be classified in the industrial classification as computer manufacturing because it originated from a firm in that industry.

Data on exports and imports represent the market value of products and services in international trade. Exports of products are assigned by the importing country's port of entry to a single country of origin. For goods manufactured in multiple countries, the country of origin is determined by where the product was "substantially transformed" into its final form.

The value of product trade entering or exiting a country's ports may include the value of components, inputs, or services classified in different product categories or originating from countries other than the country of origin. For example, China is credited with the full value (i.e., factory price plus shipping cost) of a smart phone when it is assembled in China, although made with components imported from other countries. In these data, countries whose firms provide high-value services such as design, marketing, and software development are typically not credited for these contributions.

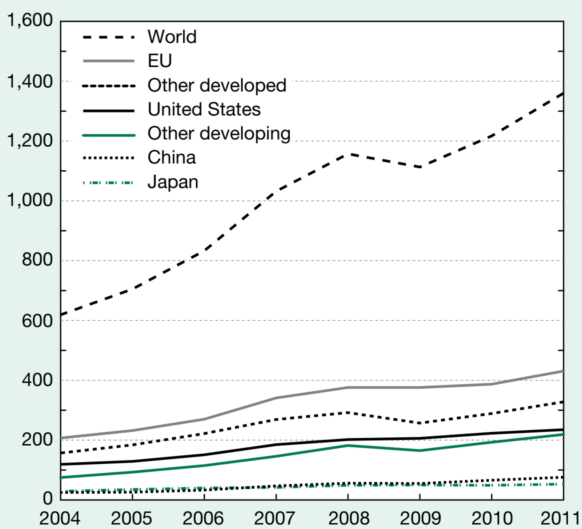
* HS is a system for classifying goods traded internationally that was developed under the auspices of the Customs Cooperation Council. Beginning on 1 January 1989, HS numbers replaced schedules previously adhered to in more than 50 countries, including the United States. For more information, see http://www.census.gov/foreign-trade/guide/sec2.html#htsusa.

Global Trade in Commercial Knowledge- and Technology-Intensive Goods and Services

Exporting goods and services to other countries is one measure of a country's economic success in the global market—the goods and services it produces compete in a world market. In addition, exports have an important advantage over domestic purchases in that they bring in income from external sources and do not consume the income of a nation's own residents.

Global trade in commercial KTI goods and services consists of four services—business, communications, computer and information, and finance—and six HT products—aerospace, communications, computers, pharmaceuticals, semiconductors, and scientific instruments.[12] Global cross-border exports of commercial KTI goods and services were an estimated $3.7 trillion, consisting of $2.3 trillion of exports of HT products and $1.4 trillion of commercial KI services (figure 6-20; appendix table 6-21).

Figure 6-20
Commercial KI service exports, by selected region/country/economy: 2004–11



EU = European Union; KI = knowledge intensive.

NOTES: Commercial KI service exports consist of communications, business services, financial services, and computer and information services. Financial services includes finance and insurance services. EU exports do not include intra-EU exports. Developed countries are classified as high-income economies by the World Bank. Developing countries are classified as higher- and lower-middle-income economies and low-income economies by the World Bank. The sum of the regions/countries/economies does not add to the world total due to rounding and discrepancies.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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Commercial Knowledge-Intensive Services

Global exports of commercial KI made up one-third of all commercial services. Among the commercial KI services, business services was the largest ($800 billion), followed by finance (which includes insurance) ($300 billion), computer and information services ($170 billion), and communications ($80 million).[13]

The United States, the EU, Japan, and other developed countries export $1.0 trillion in commercial KI services, comprising 77% of global exports (figure 6-20). China and other developing countries export far less than developed countries ($0.3 trillion).

Patterns and Trends in Developing Countries

Exports of developing countries make up a small share (22%) of global exports of commercial KI services. China and India have the largest global export shares of any developing economy (6%–7% each), and they are tied as the third largest in the world, behind the United States and the EU (table 6-3; figure 6-20).[14]

India is notable for being the largest exporter of computer and information services, attesting to the strong market position of Indian firms providing IT and related services to the rest of the world (table 6-3). China and India both have substantial surpluses in trade of commercial KI services. Other developed countries have global export shares of less than 2%.

Between 2004 and 2011, cross-border commercial KI exports of developing countries nearly tripled to reach $296 billion, expanding much faster than in developed countries but from a much lower base (figure 6-20). The global share of developing countries rose from 16% to 22% during this period.

China's exports tripled during this period, resulting in its global export share climbing from 4% to 7% (table 6-3; figure 6-20). China's trade balance in commercial KI services widened from a surplus of $3 billion to $11 billion in 2010.[15]

India's exports also expanded rapidly, with its global share rising from 4% to 7%. India's surplus expanded from $11 billion to $50 billion during this period.[16]

Patterns and Trends in Developed Countries

The EU is the largest exporter of commercial KI services, with a global share of 32% (figure 6-20). The United States is the second-largest exporter, with a global share of 17%. The EU and United States both have surpluses in trade of commercial KI services in contrast to their deficits in HT product trade (table 6-4). Japan, which has a small deficit in commercial KI services trade, is the fifth-largest exporter, behind India and China.[17]

Between 2004 and 2011, growth of commercial KI exports of developed economies trailed developing economies, resulting in their global share falling from 83% to 77% (figure 6-20).

U.S. exports of commercial KI services more than doubled to reach $235 billion; the U.S trade surplus climbed from $33 billion to $52 billion (table 6-4; figure 6-20). Exports of business services, the largest component, slighted lagged overall export growth. The trade surplus in other business services increased from $29 billion to $39 billion. U.S. exports of R&D services, a component of business services, rose from $13 billion in 2006 to $22 billion in 2010. The trade surplus edged down from $4 billion to $2 billion (see sidebar, "U.S. Trade in R&D Services").

In the EU, commercial KI services grew at a similar pace, reaching more than $400 billion in 2011, with the EU's surplus more than doubling to reach $127 billion (table 6-4; figure 6-20). Among the commercial KI services, computer information services grew the fastest, nearly tripling to reach $57 billion. Exports of business services, the largest component, slightly lagged overall growth. The EU's trade surpluses of these two commercial KI exports both grew substantially. EU's exports of financial services (which include insurance) also grew rapidly with the surplus widening from $25 billion to $51 billion.

High-Technology Goods

Global HT product exports—aircraft and spacecraft; computers; communications; semiconductors; pharmaceuticals; and testing, measuring, and control instruments—were $2.3 trillion in 2012, making up 16% of the $14.7 trillion in exports of all manufactured goods (figure 6-21; appendix tables 6-21 and 6-24). Among the HT products, ICT products—communications, computers, and semiconductors—are the largest, with a collective value of $1.4 trillion (appendix tables 6-25–6-28). The remaining three industries—testing, measuring, and control instruments; pharmaceuticals; and aircraft and spacecraft—range from $200 billion to $400 billion each (appendix tables 6-29–31).

Table 6-3
India's and China's trade in commercial KI services: 2011
(Billions of dollars)

Category	India Exports	India Imports	India Balance	China Exports	China Imports	China Balance
All commercial KI services	94	43	50.7	76	65	10.9
Computer information services	44	2	41.8	12	4	8.3
Financial services	9	14	-5.5	4	20	-16.6
Other business services	39.5	25.5	14.1	58.3	39.6	18.7
Communications services	1.7	1.4	0.3	1.7	1.2	0.5

KI = knowledge intensive.

NOTES: Commercial KI services trade consists of communications, business services, financial services, computer and information services, and other business services. Financial services includes finance and insurance.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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Table 6-4
U.S. and EU commercial KI services trade, by category: 2004, 2008, and 2011
(Billions of dollars)

Category	2004 Exports	2004 Imports	2004 Balance	2008 Exports	2008 Imports	2008 Balance	2011 Exports	2011 Imports	2011 Balance
United States									
All commercial KI services	118.9	86.4	32.5	201.7	165.7	36.0	235.1	183.6	51.5
Computer and information services	8.7	8.6	0.1	13.1	16.9	-3.8	15.5	24.5	-9.0
Financial services	43.7	40.2	3.5	72.2	76.1	-3.9	81.0	72.8	8.2
Other business services	61.6	32.3	29.3	101.8	64.3	37.5	117.2	78.2	39.0
Communications services	4.9	5.2	-0.3	10.3	8.4	1.9	12.9	8.1	4.8
EU									
All commercial KI services	207.5	141.1	52.7	376.2	252.5	123.9	431.6	274.7	126.6
Computer and information services	20.2	10.0	7.3	44.7	18.8	20.3	57.1	20.3	30.4
Financial services	49.8	24.9	41.6	93.1	40.0	54.7	96.3	45.5	41.6
Other business services	129.3	97.2	4.8	220.2	175.4	50.0	254.2	187.6	53.0
Communications services	8.2	9.0	-1.0	18.2	18.3	-1.1	24.0	21.2	1.7

EU = European Union; KI = knowledge intensive.

NOTES: Commercial KI services trade consists of communications, other business services, financial services, and computer and information services. Financial services includes finance and insurance. EU trade does not include intra-EU trade.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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The bulk of global exports ($1.4 trillion) originate from developed countries—primarily from the EU, the United States, Japan, and several Asian economies, including Singapore, South Korea, and Taiwan (figure 6-21; appendix tables 6-21 and 6-32). A large share of HT exports of developed countries is made up of components and inputs that are imported by China, Mexico, and other developing countries for final assembly. Exports of developing countries, which make up $0.9 trillion, are largely finished goods imported by developed countries (figure 6-21).

U.S. Trade in R&D Services

Trade in research and development services is part of U.S. trade in business services, a component of commercial KI services. In 2011, companies located in the U.S. exported $24 billion in these services and imported $22 billion, based on Bureau of Economic Analysis (BEA) statistics.* Most of this trade occurs between affiliated parties, that is, within multinational companies (MNCs) (appendix table 6-22).

Details by regions and countries (available for total trade, not by affiliation) show that Europe is the top destination for U.S. R&D services exports, with a 64.9% share in 2011. For R&D services imports, Europe is also the largest trading partner but with a lower share, at 46.6% in 2011. The Asia-Pacific region was the second-largest destination for R&D services exports, receiving 15.9% of U.S. exports in these services. The region's share as a source of imports was higher, at 29.4% in 2011.

Data for earlier years were collected under the category "research, development, and testing (RDT) services" (appendix table 6-23). These data show that U.S. exports of RDT services rose from $13 billion to $24 billion between 2006 and 2010. The trade surplus fell from $4 billion to $2 billion during this period. The European imports share of RDT services declined steadily from 62.3% in 2006 to 49.4% in 2010. At the same time, the share of RDT services imports from the Asia-Pacific region increased from 17.4% in 2006 to 22.7% in 2007 to just below 30% annually from 2008 to 2010.

R&D and testing services imports from the Asia-Pacific region increased most notably from India (from $427 million in 2006 to $1.6 billion in 2010), China (from $92 million to $955 million) and Japan (from $550 million to $1.3 billion). This trend is consistent with increased R&D activities in these countries both overall (gross expenditures in R&D) and by affiliates of U.S. MNCs (see the "International Comparisons of R&D Performance" and "R&D by Multinational Companies" sections in chapter 4).

* Statistics for 2011 are from the Benchmark Survey of Transactions in Selected Services and Intellectual Property with Foreign Persons. See appendix table 6-22 for details.

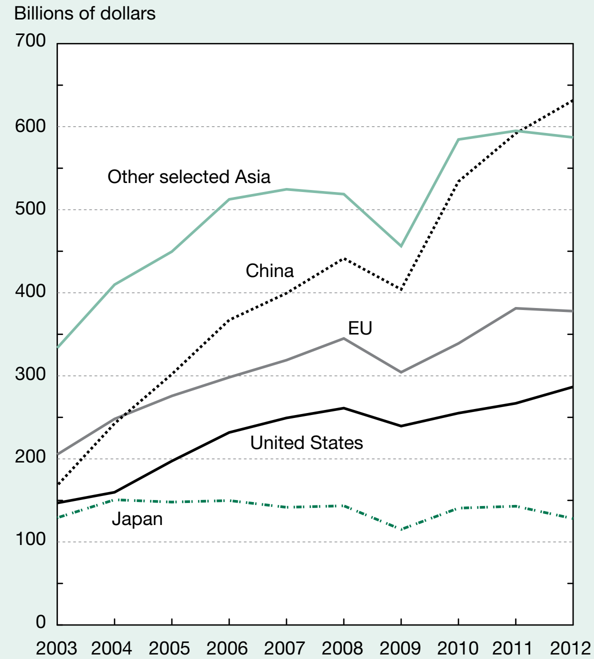
Between 2003 and 2012, global HT exports doubled to reach $2.3 trillion (appendix table 6-21). The HT share of manufactured exports declined from 22% to 16% during this period (appendix table 6-24).

Patterns and Trends in Developing Countries

China is the largest exporter of HT products among developing countries and is also the world's largest exporter, with a 28% share of global HT exports (table 6-5; figure 6-21; appendix table 6-21). Other developing countries have global shares of 3% or less.

Between 2003 and 2012, HT exports of developing countries grew twice as fast as those of developed countries. As a result, the developing countries increased their share of global HT exports from 29% to 40% (figure 6-21; appendix table 6-21). China grew the fastest among the developing countries, with its exports reaching $632 billion, becoming the world's largest exporter. China's trade surplus climbed from $30 billion to $280 billion during this period.

Figure 6-21
Exports of HT products, by selected region/country/economy: 2003–12



EU = European Union; HT = high technology.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Phillippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2013). See appendix table 6-21.

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However, because many of China's exports consist of inputs and components imported from other countries, China's trade surplus is likely much less in value-added terms (see sidebar, "International Initiative to Measure Trade in Value-Added Terms").

China's ICT exports, which dominate China's HT product exports, more than tripled to reach almost $560 billion during this period (table 6-5; appendix tables 6-25–6-28). China's ICT trade surplus expanded from almost $40 billion to over $280 billion. Its exports of testing, measuring, and control instruments grew at the same pace to reach almost $60 billion (appendix table 6-31).

Trends varied widely among other developing countries (appendix table 6-21):

- Vietnam grew the fastest of any developing country, with its HT exports growing from less than $1 billion to $17 billion. Vietnam has become a low-cost location for assembly of cell phones and other ICT products, with some firms shifting production out of China and other developing countries, where labor costs are higher.
- India's exports rose sevenfold to reach $26 billion due to expansion in pharmaceuticals and ICT products.

Patterns and Trends in Developed Countries

The bulk of global exports of HT goods ($1.4 trillion) originate from developed countries—primarily the EU, the United States, Japan, and several Asian economies (figure 6-21; appendix tables 6-21 and 6-32). The EU and the United States are the largest and second-largest global exporters among developed economies. Japan, South Korea, and Taiwan are the next-largest exporters, each with a global share of between 6% and 8%.

Between 2003 and 2012, exports of developed economies nearly doubled to reach $1.4 trillion in 2012 (figure 6-21; appendix table 6-21). Because exports of developing economies grew much faster than developed economies, the global share of developed economies fell from 71% to 60%.

In the United States, HT product exports grew slightly faster than the average for all developed economies' exports (appendix table 6-21). The U.S. global share slipped from 14% to 13%. The U.S. HT product trade position, which had been in balance in the late 1990s, experienced a widening deficit during this period, going from $88 billion to $130 billion.[18]

U.S. growth of HT product exports was led by pharmaceuticals and by aircraft and spacecraft (appendix tables 6-29 and 6-30). Pharmaceutical exports more than doubled in value to reach $39 billion, with the trade deficit widening from $13 billion to $24 billion. Exports of aircraft and spacecraft climbed to $96 billion, with the U.S. trade surplus at nearly $80 billion in 2012, up from $21 billion in 2003.

Exports of ICT products, the largest component, grew slower than the average for all HT products to reach $94 billion (appendix tables 6-25–6-28). The U.S. trade deficit in ICT products widened from $95 billion to $192 billion.

The EU exhibited a similar trend, with growth in its HT product exports led by aircraft and spacecraft, pharmaceuticals, and testing, measuring, and control instruments (appendix tables 6-29–6-31). The trade surpluses in these three products widened substantially. The EU's trade deficit in ICT products deepened from $65 billion to $112 billion (appendix tables 6-25–6-28).

Other major Asian exporters—Japan, South Korea, and Taiwan—showed divergent trends (appendix table 6-21). Japan's exports trailed the average for all developed countries, with its global share falling from 12% to 6%. Japan's decline from an export powerhouse in electronics reflects its lengthy economic stagnation, the financial difficulties of Japanese electronics firms, and Japanese companies offshoring their production to Taiwan, China, and other lower-cost locations.

Table 6-5
HT product exports, by selected region/country/economy: 2012
(Billions of dollars)

Region/country/economy	All HT products	ICT	Aircraft and spacecraft	Pharmaceuticals	Testing, measuring, and control instruments
China	631.7	557.1	3.4	13.5	57.7
EU	377.9	105.3	51.4	141.9	79.3
United States	286.7	94.3	96.3	38.7	57.4
Japan	128.1	74.2	4.5	4.8	44.6
Other selected Asia	560.8	457.0	6.1	15.9	81.8

EU = European Union; HT = high technology; ICT = information and communications technologies.

NOTES: HT products include aircraft and space vehicles, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. ICT products include communications, semiconductors and computers, and office machinery. China includes Hong Kong. Exports of China exclude exports between China and Hong Kong. Exports of the United States exclude exports to Canada and Mexico. The EU excludes Cyprus, Luxembourg, Malta, and Slovenia. Exports of the EU exclude exports to EU member countries. Other selected Asia includes Malaysia, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2013). See appendix tables 6-21 and 6-25–6-30.

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Taiwan's HT exports doubled during this period, and it surpassed Japan in 2010 to become the largest developed Asian exporter of HT products. South Korea's HT exports also doubled, and it reached Japan's level in 2012. Both of these economies' rapid gains in HT exports were due to growth of ICT product exports, which make up most of their HT exports (appendix tables 6-25–6-28).

U.S. Trade in Advanced Technology Products

The Census Bureau has developed a classification system for internationally traded products based on the degree to which they embody new or leading-edge technologies. This classification system has significant advantages for determining whether products are HT and may be a more precise and comprehensive measure than the product classification based on the OECD classification for HT industry production. It categorizes ATP trade into 10 major technology

International Initiative to Measure Trade in Value-Added Terms

The Organisation for Economic Co-operation and Development (OECD)/World Trade Organization (WTO) Trade in Value Added (TiVA) initiative is developing estimates of trade measured in value-added terms to complement conventional measures of trade. In a world where goods and services are often produced through global supply chains, value-added measures of international trade have two substantial advantages over conventional trade measures. First, they record the amount of global trade more accurately; they record value only once, in the country in which it is added. In contrast, conventional trade measures overstate the value of internationally traded goods and services, recording the entire (gross) value of an item every time it crosses a national border. Second, value-added measures produce better estimates of national contributions to the value of goods and services in international trade. In contrast, conventional trade measures attribute the entire (gross) value of the goods and services a country trades to that country, even if a portion of the value was produced by other countries in the supply chain. The OECD's estimate of the U.S. trade balance in iPhones shows that the United States has a much smaller estimated trade deficit with China, the location of final assembly and export of iPhones, and larger trade deficits with countries that supply inputs to the iPhone (table 6-C).

OECD/WTO estimates of trade in value-added terms are derived from OECD country-level input-output tables. Input-output tables track the interrelationships among domestic industries and also between domestic industries and consumers—households, government, industry, and export customers. OECD/WTO built international input-output tables that link exports in one country to the purchasing industries or final-demand consumers in the importing country. The international input-output tables estimate trade among countries on an industry basis using coefficients derived from bilateral product and services trade data, which are not collected on an industry basis.

OECD/WTO estimates of trade in value-added terms assume that the share of imports in any product consumed directly as intermediate consumption or final demand (except imports) is the same for all users. This assumption is reasonable for developed countries, where there is little product differentiation between what is produced for export and what is produced for the domestic market. This assumption is probably less realistic for developing countries because the import content of exports is usually higher than the import content of products destined for domestic consumption.

The most recent version of the OECD/WTO database, released in May 2013, covers 58 economies (including all OECD countries, Brazil, China, India, Indonesia, Russia, and South Africa) and the years 1995, 2000, 2005, 2008, and 2009. Trade in value-added indicators and additional information are available at http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

Table 6-C
U.S. trade balance in iPhones, by selected country/economy
(Millions of dollars)

Type of trade	China	Germany	South Korea	Taiwan	ROW
Balance (gross)	-1,646	0	0	0	0
Balance (value added)	-65	-161	-800	-207	-413

ROW = rest of world.

SOURCE: Organisation for Economic Co-operation and Development, Trade in Value-Added: Concepts, Methodologies and Challenges, http://www.oecd.org/sti/ind/49894138.pdf, accessed 15 March 2013.

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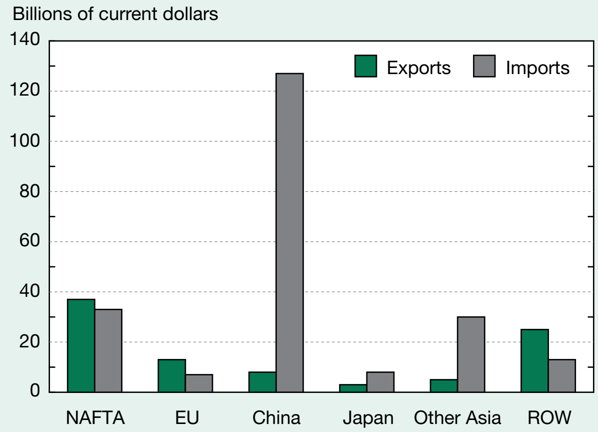
areas, including aerospace, biotechnology, electronics, ICT, life sciences, and optoelectronics.[19]

U.S. trade in ATP products is an important component of overall U.S. trade, accounting for about one-fifth of combined nonpetroleum exports and imports. Five technology areas—ICT, aerospace, electronics, life sciences, and optoelectronics—account for more than 90% of the total value of U.S. ATP exports and imports (table 6-6; appendix tables 6-33–6-38). ICT is the largest, with a share of 44%, followed by aerospace, with a 21% share. Life sciences and electronics each have a share of 11%. Optoelectronics has a share of 5%. The largest U.S. ATP trading partners are China; other Asian countries, including Japan, South Korea, and Malaysia; the EU; and NAFTA partners Canada and Mexico.

In 2012, the United States exported $305 billion in ATP goods and imported $396 billion, resulting in a deficit of $92 billion (figures 6-22 and 6-23; appendix table 6-33). Trends varied widely by technology area (table 6-6):

- Trade in ICT products produced a deficit of $128 billion, the largest of any technology area. The largest trading partner is China, which dominates this area.
- In the life sciences area, the United States ran a small deficit of $12 billion, largely with the EU.
- The United States has a surplus of $66 billion in aerospace, the largest of any technology area. The largest trading partner in this area is the EU.

Figure 6-22
U.S. advanced technology product trade in ICT, by selected region/country/economy: 2012



EU = European Union; ICT = information and communications technology; NAFTA = North America Free Trade Agreement; ROW = rest of world.

NOTES: China includes Hong Kong. Other Asia includes Malaysia, Singapore, South Korea, and Taiwan. NAFTA includes Canada and Mexico. Advanced technology product trade is classified by the Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, ICT, life sciences, optoelectronics, nuclear, and weapons.

SOURCE: U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Trade database, http://www.census.gov/foreign-trade/statistics/country/index.html, accessed 15 January 2013. See appendix table 6-34.

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Table 6-6
U.S. ATP trade in selected technology areas, by selected region/country/economy: 2012
(Billions of dollars)

Technology area	NAFTA	EU	China	Japan	Other Asia	ROW
Aerospace						
Exports	8.2	29.6	11.0	8.1	9.6	38.5
Imports	9.0	20.2	0.7	4.7	1.2	3.2
Balance	-0.9	9.3	10.3	3.4	8.4	35.2
Electronics						
Exports	8.5	2.4	6.6	1.3	13.2	9.2
Imports	2.6	2.5	3.1	2.6	12.3	10.8
Balance	5.9	-0.1	3.4	-1.3	0.9	-1.5
ICT						
Exports	36.6	13.5	8.0	3.5	5.1	24.7
Imports	33.3	7.0	127.4	8.4	30.5	12.9
Balance	3.3	6.5	-119.4	-4.9	-25.4	11.8
Life sciences						
Exports	3.7	11.8	3.3	3.7	2.0	7.1
Imports	4.4	27.2	2.1	1.8	2.0	7.0
Balance	-0.7	-15.4	1.2	2.0	0.0	0.1

ATP = advanced technology products; EU = European Union; ICT = information and communications technology; NAFTA = North American Free Trade Agreement; ROW = rest of world.

NOTES: China includes Hong Kong. EU includes current member countries. Other Asia includes Malaysia, South Korea, Singapore, and Taiwan. ATP trade is classified by the Census Bureau and consists of advanced materials, aircraft and space vehicles, biotechnology, electronics, flexible manufacturing, information and communications technology, life sciences, optoelectronics, nuclear, and weapons.

SOURCE: U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Trade database, http://www.census.gov/foreign-trade/statistics/country/index.html, accessed 15 January 2013. See appendix tables 6-34–6-37.

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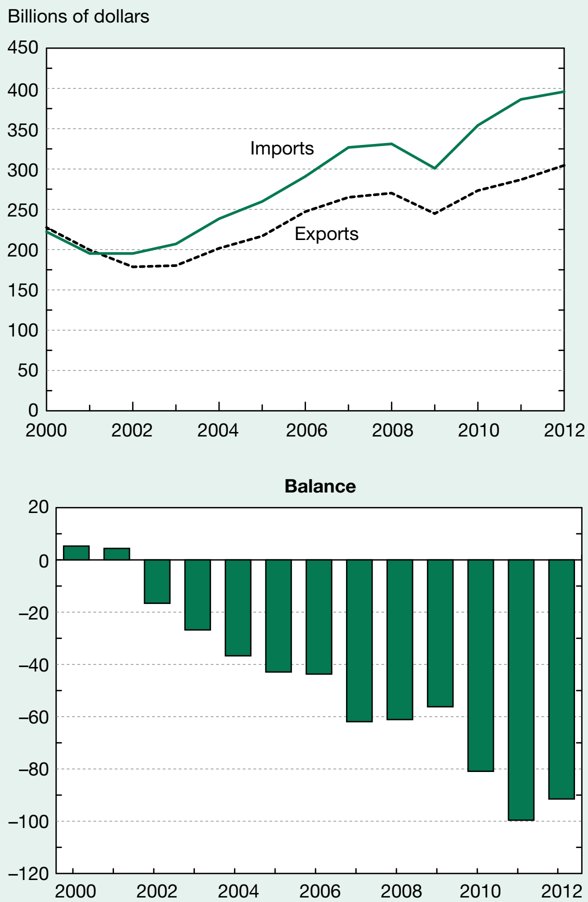
- ♦ The United States had a small surplus ($7 billion) in electronics. Leading trading partners are Malaysia and South Korea.

Trends in U.S. Advanced Technology Products Trade

Between 2003 and 2012, U.S. ATP imports grew faster than exports, resulting in the trade deficit widening from $27 billion to $92 billion (figure 6-23; appendix table 6-33). Among the four largest technology areas, exports of life sciences grew the fastest (143%), with imports increasing at the same rate, resulting in the trade deficit remaining roughly stable (appendix table 6-37).

Figure 6-23
U.S. trade in advanced technology products: 2000–12



NOTE: Advanced technology product trade is classified by the Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications technologies, life sciences, optoelectronics, nuclear, and weapons.

SOURCE: U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Trade database, http://www.census.gov/foreign-trade/statistics/country/index.html, accessed 15 January 2013. See appendix table 6-33.

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Aerospace exports grew the next fastest, and outpaced growth of imports, resulting in the trade surplus widening from $27 billion to $66 billion (appendix table 6-35). Trends in exports and imports in these two technology areas have largely been driven by trade with the EU, the largest partner in these two areas.

Exports of ICT products grew the slowest among these four technology areas, with much faster growth of imports (appendix table 6-34). The trade deficit in ICT products more than doubled to reach nearly $130 billion, with the trade deficit with China reaching nearly $100 billion. As in U.S. HT international trade, the rising deficit in U.S. ATP trade has largely occurred in ICT products and with China.

In electronics, the United States had a surplus of between $16 billion and $25 billion for much of the 2000s. Between 2011 and 2012, the trade surplus fell to $7 billion because of a decline in exports combined with an increase in imports (appendix table 6-36).

U.S. Multinational Companies in Knowledge- and Technology-Intensive Industries

The Bureau of Economic Analysis (BEA) conducts an annual survey of U.S. multinationals that includes firms in KTI industries. The BEA data are not directly comparable with the world industry data used in the previous sections. However, the BEA data provide additional information on the globalization of activity and employment in U.S. multinationals in these industries.

Commercial Knowledge-Intensive Service Industries

U.S. multinationals in commercial KI services industries generated $1.1 trillion in value added in 2010 (preliminary), of which $873 billion (76%) occurred in the United States (appendix table 6-39). Financial services ranks first by value added ($471 billion), followed by information services ($384 billion) and business services ($297 billion). Production in business services was the most globalized, as measured by the distribution between U.S. and foreign value added, with 31% of value added originating from foreign economies in 2010 (figure 6-24). Financial services were the next highest (28%), followed by information services (15%).

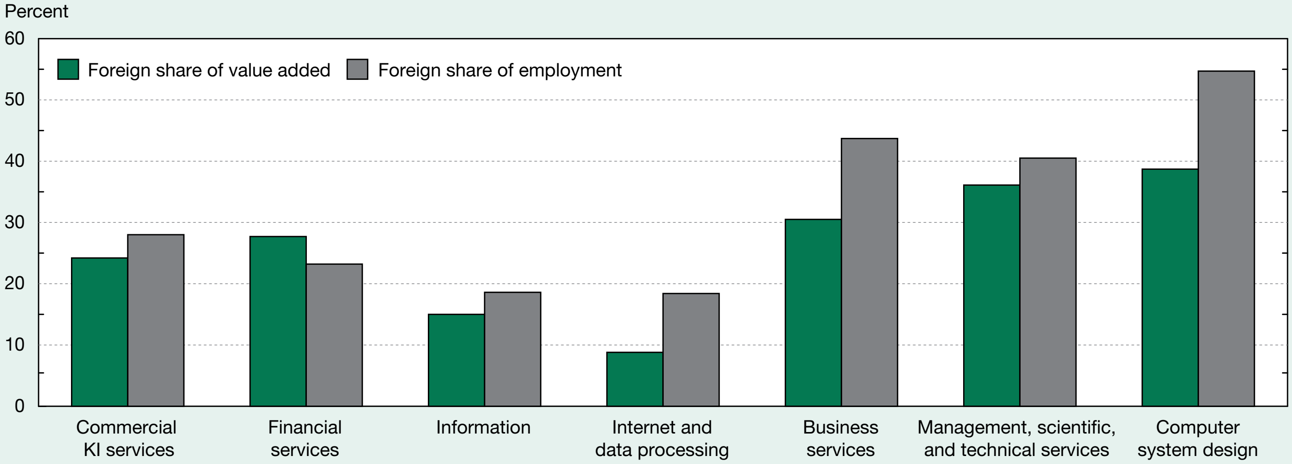
U.S. multinationals in commercial KI services industries employed 7.4 million workers worldwide, of whom 5.4 million (72%) were employed in the United States (appendix table 6-39). Employment was highest in financial services, at 2.5 million, followed by 1.6 million employed in information services and 1.2 million employed in business services. Employment was most globalized in business services (foreign share of 44%), followed by financial services (24%) and information services (19%) (figure 6-24).

High-Technology Manufacturing Industries

U.S. multinationals in the HT manufacturing industries (excluding aircraft and spacecraft) generated more than $400 billion worldwide in value added in 2010 (preliminary), of which about two-thirds originated in the United States (figure 6-25; appendix table 6-39). Production in the computer industry was the most globalized, as measured by the distribution between U.S. and foreign value added, with 45% of value added originating from foreign locations in 2010 (figure 6-25). Pharmaceuticals was the second highest (40%), followed by semiconductors (35%) and then by testing, measuring, and control instruments (28%). Communications is the least-globalized industry, with 17% of value added produced outside of the United States.

U.S. multinationals in HT manufacturing employed 2.4 million workers worldwide, with 1.2 million workers (about

Figure 6-24
Globalization indicators of U.S. multinationals in commercial KI services: 2010



KI = knowledge intensive.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the Organisation for Economic Co-operation and Development and include business, financial, and communications. Internet and data processing are part of communications. Management, scientific, and technicals and computer system design are part of business services.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies (2009–10), http://www.bea.gov/international/di1usdop.htm, accessed 15 February 2013. See appendix table 6-39.

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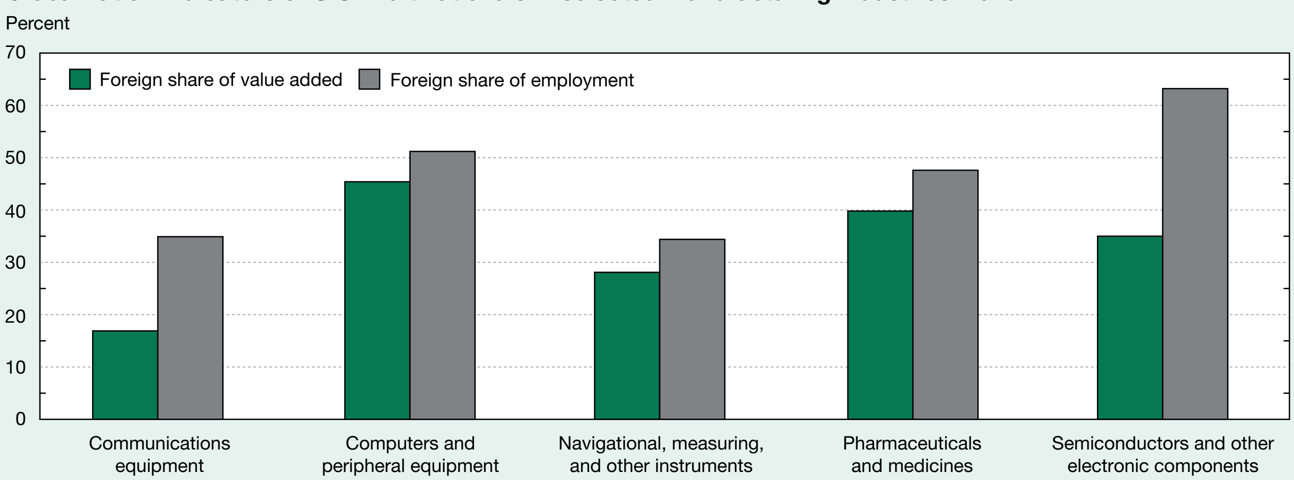
Figure 6-25
Globalization indicators of U.S. multinationals in selected manufacturing industries: 2010



NOTE: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies, 2009–10, http://www.bea.gov/international/di1usdop.htm, accessed 15 February 2013. See appendix table 6-39.

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50%) employed in the United States in 2010 (preliminary) (appendix table 6-39). More than 60% of the semiconductor workforce of 600,000 workers is employed abroad, the highest share among these industries (figure 6-25). Multinational companies in two industries—computers and pharmaceuticals—employ around 50% of their workforce abroad. The communications and testing, measuring, and control instruments industries have less than 40% of their workforces employed abroad.

U.S. and Foreign Direct Investment in Knowledge- and Technology-Intensive Industries

Foreign direct investment (FDI) has the potential to generate employment, raise productivity, transfer skills and technology, enhance exports, and contribute to long-term economic development (Kumar 2007). Receipt of FDI may indicate a developing country's emerging capability and integration with countries that have more established industries. FDI in specific industries may suggest the potential for these industries' evolution and the creation of new technologies.

This section uses data from BEA on U.S. direct investment abroad and foreign investment in the United States in KTI industries. The rising volume of trade by U.S.-based KTI firms has been accompanied by increases in U.S. direct investment abroad and FDI in the United States. Estimates of U.S. direct investment abroad and FDI in the United States are lower-bound estimates because a substantial share of outward and inward investment is allocated to holding companies that own companies in other industries.

U.S. Direct Investment Abroad

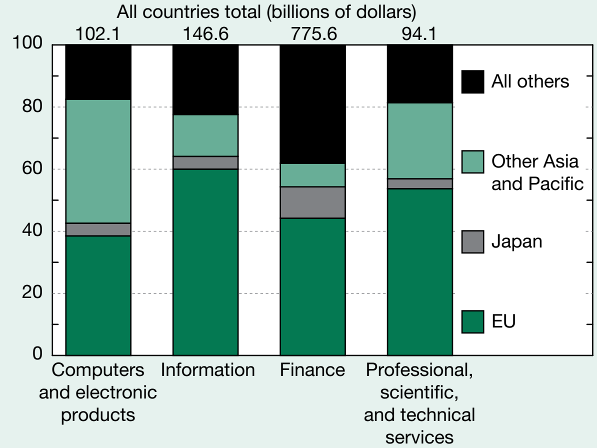
The stock of U.S. direct investment abroad in computer and electronic products, which includes the HT industries of communications, semiconductors, and testing, measuring, and control instruments, was $102 billion in 2012 (figure 6-26). The Asia and Pacific region receives 43% of U.S. direct investment abroad.[20] The EU is the next-largest recipient, with a share of 39%.

The stock of U.S. direct investment abroad in commercial KI services industries was $1.0 trillion in 2012 (figure 6-26). Financial services accounted for most U.S. direct investment abroad, with far smaller shares for information and professional, scientific, and technical services. The EU is the largest recipient in these three industries, with shares ranging from 44% to 54%. The Asia and Pacific region, including Japan, is the next largest, with shares of 18%–28% in these industries.

Foreign Direct Investment in the United States

The stock of inward FDI in U.S. computer electronics manufacturing industries was $61 billion in 2012, less than the amount the United States invested abroad in these industries (figure 6-27). Limited data on the geographical region show that the Asia and Pacific region is the largest investor,

Figure 6-26
U.S. outward foreign direct investment in selected industries: 2012
Share (percent)



EU = European Union.

NOTES: Finance excludes depository institutions. Other Asia and Pacific includes Australia, China, Hong Kong, India, Indonesia, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand, and others.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies 2012, http://www.bea.gov/international/di1usdop.htm, accessed 10 August 2013.

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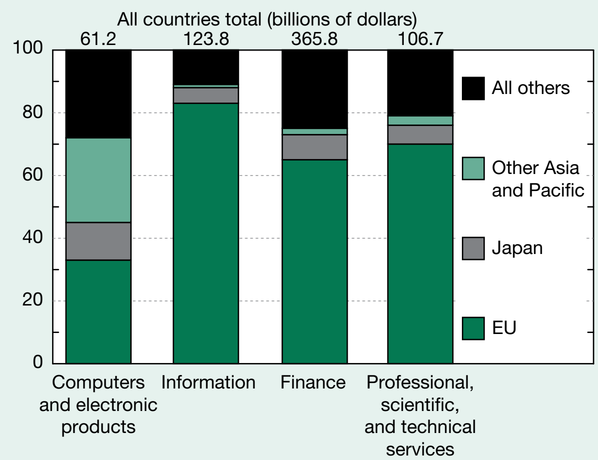
Figure 6-27
Foreign direct investment in selected U.S. industries, by selected region/country/economy: 2012
Share (percent)



EU = European Union.

NOTES: Investment in billions of dollars is shown above each industry. Finance excludes depository institutions. Other Asia and Pacific includes Australia, China, Hong Kong, India, Indonesia, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand, and others.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 January 2013.

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with a share of 39%. The EU is the second largest, with a share of 33%.

Similarly, the stock of inward FDI in U.S. commercial KI services, at $596 billion in 2011, was less than the amount the United States invested abroad in these industries (figure 6-27). The EU is the largest investor in these industries, with shares of 65%–83% in these industries.

Innovation-Related Indicators of the United States and Other Major Economies

The fourth section of this chapter examines several innovation-related measures in industries, with a focus on KTI industries. OECD defines innovation as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method" (OECD/Eurostat 2005:46–47). Innovation is widely recognized as instrumental to the realization of commercial value in the marketplace and as a driver of economic growth. New ICT technologies, for example, have stimulated the creation of new products, services, and industries that have transformed the world economy over the past several decades.

This section presents data on how innovation activity varies among U.S. industries, using information from NSF's BRDIS. The section also includes three indicators of activities that can facilitate innovation but do not themselves constitute innovation. Two of these, patents and trade in royalties and fees, are indicators of invention—they protect intellectual property in inventions that can have value for commercial innovations. The third indicator concerns early stage financing for U.S. HT small businesses, which can be an important milestone in the process of bringing new products and services to market.

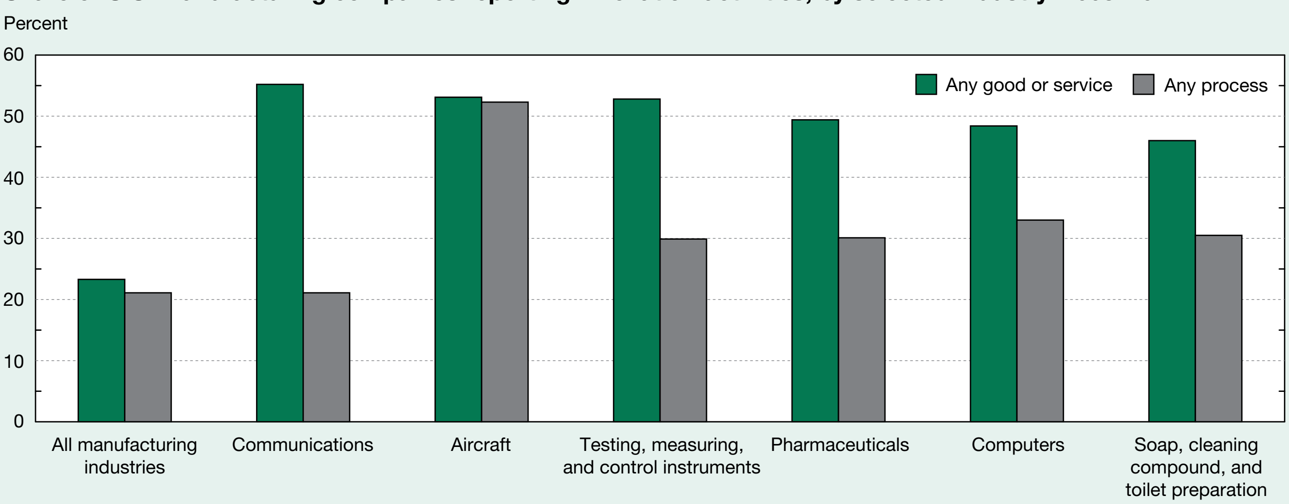
Innovation Activities by U.S. Businesses

BRDIS provides innovation indicators that are representative of all U.S.-located businesses with five or more employees. Survey results indicate which kinds of companies introduced new goods, services, or processes between 2008 and 2010.[21] Data from the 2010 survey suggest that U.S. KTI industries have a much higher incidence of innovation than other industries.

In the U.S. manufacturing sector, five of the six HT manufacturing industries—aircraft; communications; computers; pharmaceuticals; and testing, measuring, and control instruments—reported rates of product and process innovation that were at least double the manufacturing sector average (figure 6-28). Most of these industries reported significantly higher rates of innovation in both goods and services, suggesting that high rates of innovation by manufacturing companies go hand-in-hand with innovations in services.

Several of these industries—notably, aerospace; computers; pharmaceuticals; and testing, measuring, and control instruments—reported higher-than-average rates of process innovations, particularly in production methods, logistics, and delivery methods. Innovation is also higher in several commercial KI services industries in comparison to other nonmanufacturing industries (figure 6-29).[22] Software firms lead in incidence of innovation, with 69% of companies reporting the introduction of a new product or service, compared to the 9% average for all nonmanufacturing industries.

Figure 6-28
Share of U.S. manufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced from 2008 to 2010. Figures are preliminary and may later be revised. Data may not be internationally comparable. The sum of yes plus no percentages may not add to 100% due to item response to some innovation question items.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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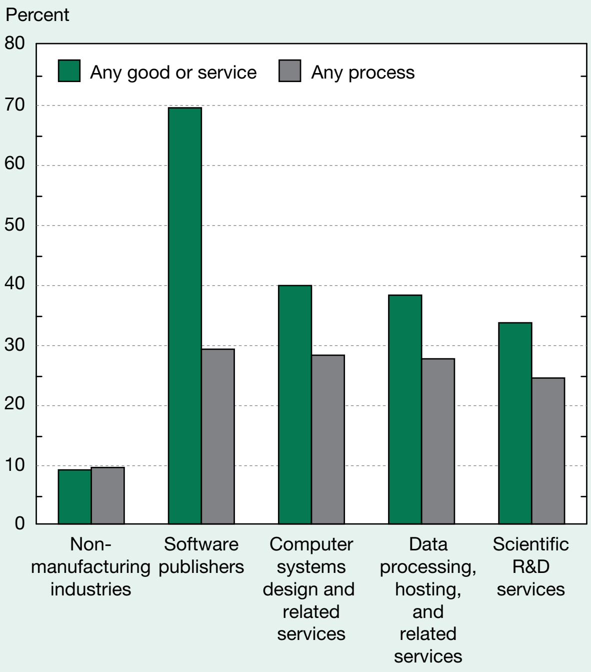
Innovation is also three to four times higher than the nonmanufacturing average in three other industries—computer systems design, data processing and hosting, and scientific R&D services.

Global Trends in Patenting

To foster innovation, nations assign property rights to inventors in the form of patents. These rights allow the inventor to exclude others from making, using, or selling the invention for a limited period in exchange for publicly disclosing details and licensing the use of the invention.[23] Inventors obtain patents from government-authorized agencies for inventions judged to be "new . . . useful . . . and . . . nonobvious."[24]

Patenting is an intermediate step toward innovation, and patent data provide indirect and partial indicators of innovation. Not all inventions are patented, and the propensity to patent differs by industry and technology area. Not all patents are of equal value, and not all foster innovation—patents may be obtained to block rivals, negotiate with competitors, or help in infringement lawsuits (Cohen, Nelson, and Walsh 2000). In HT industries, where innovation is cumulative, firms may build "thickets" of patents that impede or raise the cost of R&D and innovation (Noel and Schankerman 2009:2).

Figure 6-29
Share of U.S. nonmanufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced in 2008–10. The sum of yes plus no percentages may not add to 100% due to item nonresponse to some innovation question items. Figures are preliminary and may later be revised. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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Indeed, the vast majority of patents are never commercialized. However, the smaller number of patents that are commercialized result in new or improved products or processes or even entirely new industries. In addition, their licensing may provide an important source of revenue, and patents may provide important information for subsequent inventions and technological advances.

This discussion focuses largely on patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.[25] Although U.S. patents are naturally skewed toward U.S. inventions, these market attributes make U.S. patent data useful for identifying trends in global inventiveness.

This section also deals with patents filed in all three of the world's largest patenting centers: the United States, the EU, and Japan. Because of the high costs associated with patent filing and maintenance in these three patent offices, inventions covered by these patents are likely to be valuable.

U.S. Patent and Trademark Office Grants

The USPTO granted inventors more than 250,000 patents in 2012 (appendix tables 6-40 and 6-41). U.S. inventors were granted 120,000 patents, making them the largest recipient, with a share of nearly one-half of patents granted worldwide. Japan, the next largest, was granted 51,000 patents. The EU, ranked third, received 36,000 patents. Other developed economies, largely South Korea and Taiwan, were together granted the same number as the EU. Developing countries received 9,000 patents (less than 4% of total patents). China and India received by far the largest number of patents granted to developing countries.

The number of USPTO patents remained essentially flat at 170,000 patents between 2003 and 2009 before rising rapidly to reach 250,000 in 2012 (appendix table 6-40). The rapid growth in 2010–12 may reflect recovery from the recession, along with USPTO efforts to decrease its backlog of patent applications. The United States enacted a new patent law in 2011 that was aimed in part at reducing the backlog of USPTO patent applications.

Between 2003 and 2012, the number of USPTO patents granted to U.S.-based inventors grew from 87,000 to 120,000 patents, trailing the pace of growth of all patents (appendix table 6-40). As a result of U.S. growth lagging behind overall growth, the U.S. share fell 5 percentage points to reach 48% (figure 6-30). The decline in the U.S. share likely indicates increased technological capabilities abroad, globalization that makes patent protection in foreign countries more important, and patenting by U.S.-based inventors located abroad, such as patents granted to inventors located in subsidiaries of U.S. MNCs.

Patents granted to Japan and the EU grew slightly slower than the growth of overall patents, resulting in their shares slightly declining to 20% and 14%, respectively (figure 6-30; appendix table 6-40). Slow growth of USPTO patenting by Japan and the EU may indicate sluggish economic activity or an increased preference to patent in their home patent offices.

Patents granted to other developed economies rose three times faster than growth of all patents to reach 37,000 patents (appendix table 6-40). South Korea and Taiwan led growth of these developed economies, with their patent grants rising to 13,000 and 11,000, respectively.

Patents granted to developing countries rose exponentially (but from a very low base) to reach 9,000 patents (table 6-7; figure 6-30; appendix table 6-40). China and India led growth of developing countries, with their patents reaching 5,000 and 2,000 patents, respectively.

U.S. Patent and Trademark Office Patenting Activity by U.S. Companies

Patenting by U.S. industry provides an indication of inventive activity, mediated by the relative importance in different industries of patenting as a business strategy.

According to the NSF BRDIS survey, U.S. KTI industries account for a large share of USPTO patent grants (figure 6-31; appendix table 6-42). The BRDIS data on USPTO patents are not comparable with the USPTO patent data presented in the previous and following section.[26] U.S. HT industries were granted 29,000 of the 58,000 patents granted to all U.S. manufacturing industries in 2011. The HT industry share of patents granted to all manufacturing industries (50%) is far higher than its share of value added of all manufacturing industries (19%). The U.S. semiconductor industry was issued the largest number of patents (10,000) among these HT industries, followed by 2,000 to 5,000 each for aerospace, computers, communications equipment, pharmaceuticals, and testing, measuring, and control instruments.

U.S. commercial KI services received 46% of the 43,000 patents issued to nonmanufacturing industries in 2011 (figure 6-31; appendix table 6-42). These industries' share of patents is much higher than their value-added share of all

Table 6-7
USPTO patents granted for selected countries: 2003, 2008, and 2012

Country	2003	2008	2012
Brazil	132	101	201
China	613	1,607	5,351
India	354	651	1,756
Malaysia	48	159	213
South Africa	111	90	140

USPTO = U.S. Patent and Trademark Office.

NOTE: Patent grants are fractionally allocated between the United States and all other countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) of the Proprietary Patent database. See appendix table 6-40.

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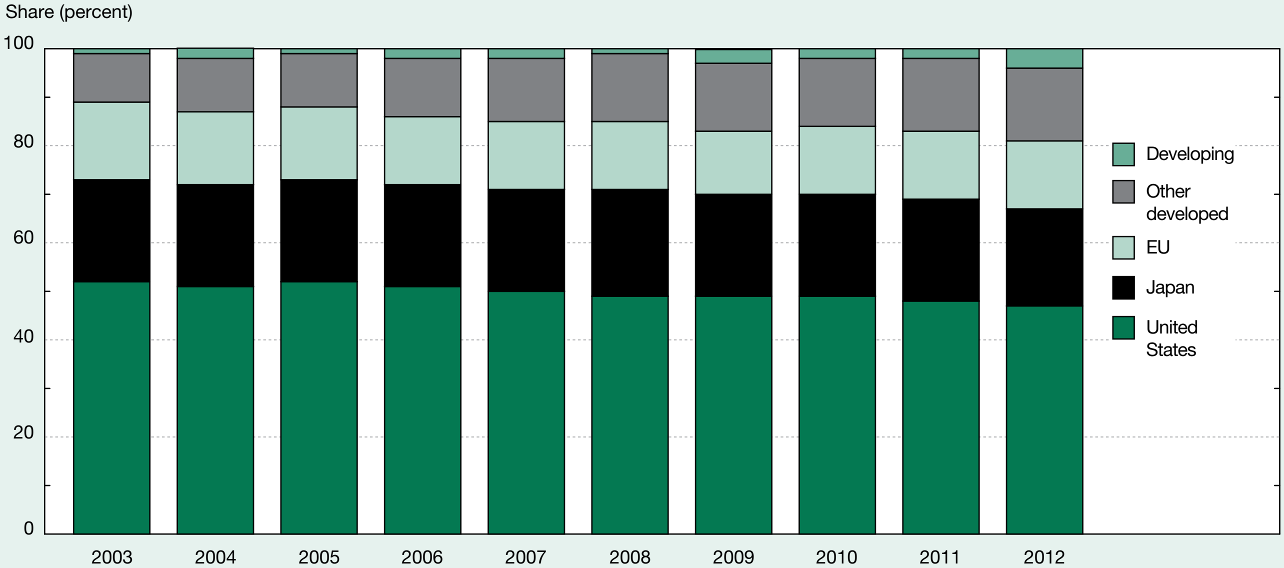
Figure 6-30
USPTO patents granted, by location of inventor: 2003–12



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: Technologies are classified by The Patent Board.™ Patent grants are fractionally allocated among countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) from Proprietary Patent database. See appendix table 6-40.

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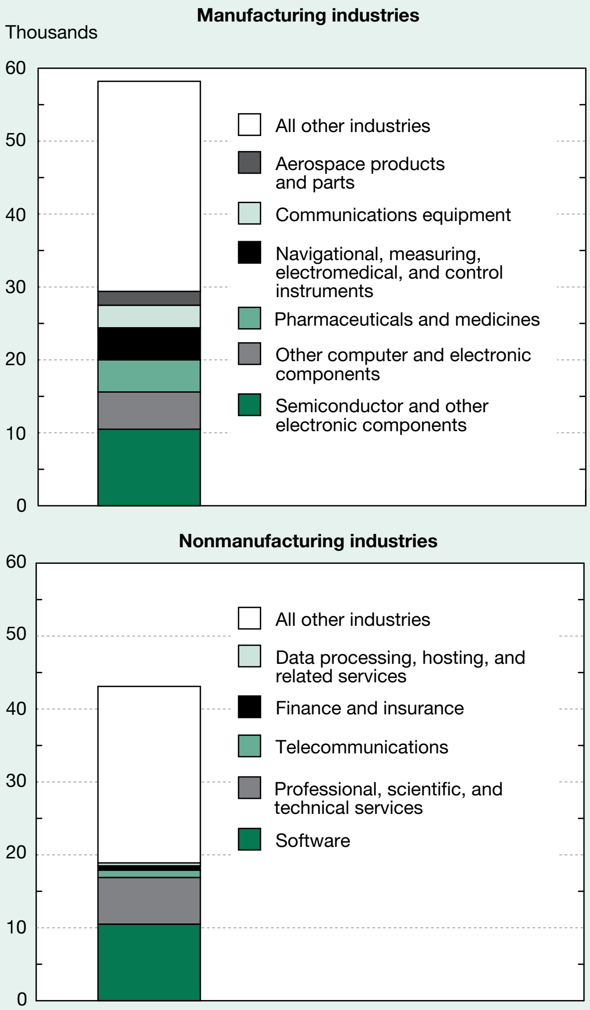
nonmanufacturing industries (32%), similar to the position of HT manufacturing industries. The software industry accounted for 10,000 patents, more than half of the patents issued to commercial KI services; professional and technical services were ranked second, with 6,000 patents. Two industries in professional and technical services—scientific R&D services and computer systems design—reported significant patenting activity.

Figure 6-31
USPTO patents granted, by selected U.S. industry: 2011



USPTO = U.S. Patent and Trademark Office.

NOTES: Detail may not add to total because of rounding. Industry classification is based on dominant business code for domestic R&D performance where available. For companies that did not report business codes, classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, counts from USPTO.gov were used to supplement survey data.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2011. See appendix table 6-42.

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U.S. Patent and Trademark Office Patents Granted, by Technology Area

This section discusses trends in four broad, NSF-classified technology areas that are closely linked to science or KTI industries—ICT; biotechnology and pharmaceuticals; medical electronics and medical equipment; and automation, control, and measuring technologies. This NSF classification assigns patents to technology areas on the basis of information contained in the patents; it is not comparable to patent data from BRDIS presented in the previous section, which classify patents based on the industry of the company to which the patent was issued.

Patents granted in the four broad, NSF-classified technology areas make up more than half of all U.S. patents:

- ♦ The largest area is ICT, which consists of networking, information processing, telecommunications, semiconductors, and computer systems (table 6-8; appendix tables 6-43–6-47). It accounts for nearly 40% of all USPTO patents.
- ♦ Health-related technologies consist of two broad areas, biotechnology and pharmaceuticals and medical electronics and medical equipment. These two technology areas each have shares of 6% (appendix tables 6-48–6-51).
- ♦ A fourth broad area includes automation and control and measuring and instrumentation technologies, with a share of 6% (appendix tables 6-52 and 6-53).
- ♦ Between 2003 and 2012, USPTO patents granted in ICT technologies more than doubled, compared to a 50% increase in patents in all technologies (appendix tables 6-43–6-47). Trends varied widely among the five ICT technology areas:
  - Patents granted in information processing and networking at least tripled to reach 14,000 and 24,000, respectively.
  - Patents in telecommunication nearly doubled to reach 17,000.
  - Patents in computer systems lagged overall growth (55%) to reach 15,000.
  - Patents in semiconductors grew the slowest (18%) to reach 16,000.
- ♦ Biotechnology and pharmaceuticals trailed growth of patents in all technologies (36% versus 50%) (appendix tables 6-48 and 6-49). Growth was particularly weak in pharmaceuticals, which grew 16%. This weak growth coincides with consolidation of the pharmaceutical industry in the last several years, stronger price and safety regulation of drugs in many developed countries, increased competition from generics, and little growth in U.S. Food and Drug Administration approval of new drugs.

Positions of Major Patenting Regions and Countries in Selected Technology Areas

This section presents shares of the United States, the EU, and several Asian countries in these four broad technology areas averaged over 2010–12. A technology area share greater (less) than the share of all patents signifies that patents by a region, country, or economy are concentrated (weaker) in a particular technology.

ICT. U.S. patenting activity is concentrated in the broad ICT technology area, with a share 4 percentage points higher than its share of all patents (figure 6-32). However, the U.S. position varies widely among the individual technology areas:

- The United States is highly concentrated in two areas—information processing and networking—with shares more than 10 percentage points higher (appendix tables 6-43 and 6-44).
- The United States has average activity in two areas—computer systems and telecommunications (appendix tables 6-45 and 6-47). The United States is weak in semiconductors, with its share more than 10 percentage points below its share of all patents (appendix table 6-46).

EU patenting activity in ICT is comparatively low (figure 6-32). Several studies suggest that the EU has lagged behind the United States in ICT technology, but the pattern may also reflect a preference of EU inventors to patent in the European Patent Office.

In Asia, Japan and Taiwan have similar ICT patterns, with an overall weakness in ICT (figures 6-32 and 6-33). They have weaker activity in three technologies—networking, information processing, and telecommunications (appendix

Table 6-8
USPTO patents granted in selected technology areas: 2003, 2008, and 2012

Technology area	2003	2008	2012
Automation, control, and measurement	11,062	12,583	15,773
Biotechnology and pharmaceuticals	10,969	9,499	14,969
ICT	40,441	51,842	90,140
Computer systems	9,789	11,148	15,260
Information processing	7,533	13,268	27,880
Networking	2,626	5,806	10,986
Semiconductors	13,108	11,080	15,272
Telecommunications	7,385	10,540	20,743
Medical electronics and equipment	9,987	6,262	14,555

ICT = information and communications technology; USPTO = U.S. Patent and Trademark Office.

NOTE: Technologies are classified by The Patent Board.™

SOURCE: The Patent Board,™ special tabulations (2013) of the Proprietary Patent database. See appendix tables 6-43–6-53.

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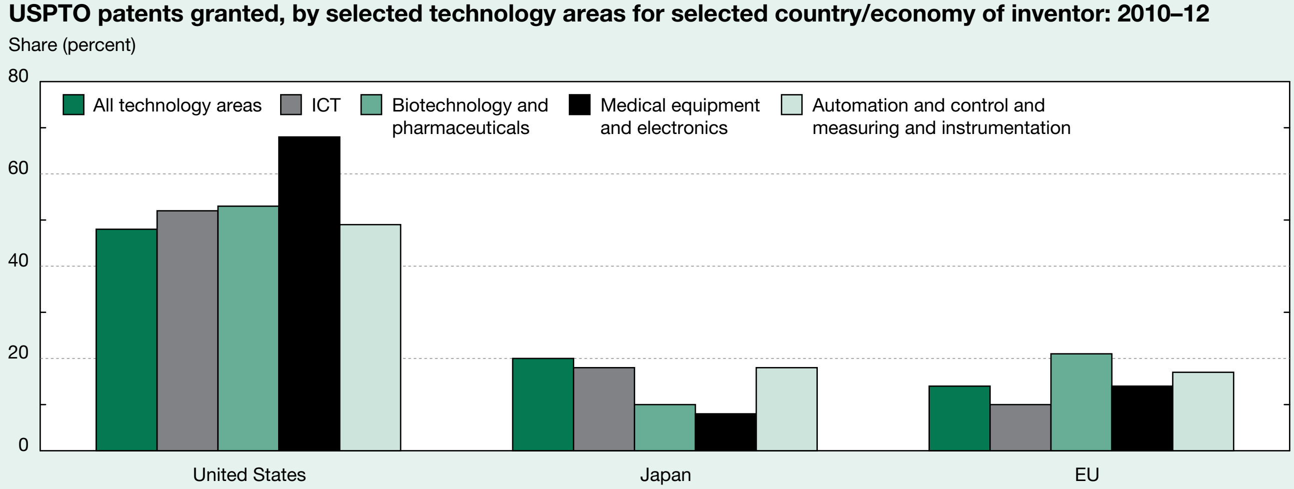
Figure 6-32
USPTO patents granted, by selected technology areas for selected country/economy of inventor: 2010–12



EU = European Union; ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office.

NOTES: Technologies are classified by The Patent Board.™ Patents are fractionally allocated among countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) from Proprietary Patent database. See appendix tables 6-40 and 6-43–6-53.

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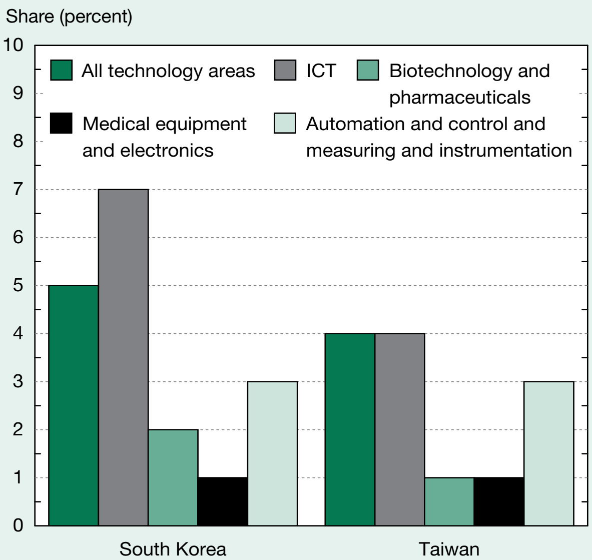
tables 6-43–45). They have concentrated patenting activity in computer systems and semiconductors (appendix tables 6-46 and 6-47).

Biotechnology and Pharmaceuticals. The United States is concentrated in this area, with a high concentration in biotechnology and a somewhat high concentration in pharmaceuticals (figure 6-32; appendix tables 6-48 and 6-49). The EU is highly concentrated in this area, with very strong activity in pharmaceuticals and above-average activity in biotechnology. South Korea and Taiwan are weak in this area (figure 6-33).

Medical Electronics and Equipment. The United States has a very high concentration in medical electronics and equipment with a share that is 20 percentage points higher than its share of all patents (figure 6-32; appendix tables 6-50 and 6-51). The United States is equally strong in the two individual technology areas. The EU's patenting activity is average in this area, and South Korea and Taiwan have much weaker activity (figure 6-33).

Automation and Control; Measuring and Instrumentation. The United States has a somewhat higher concentration in automation and control and average activity in measuring and instrumentation (figure 6-32; appendix tables 6-52 and 6-53). The EU has higher-than-average concentration in these two technology areas. South Korea and Taiwan have weaker activity in these two technology areas (figure 6-33).

Figure 6-33
USPTO patents granted, by selected technology areas for inventors located in South Korea and Taiwan: 2010–12



ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office.

NOTES: Technologies are classified by The Patent Board.™ Patents are fractionally allocated among countries/economies on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) from Proprietary Patent database. See appendix tables 6-40 and 6-43–53.

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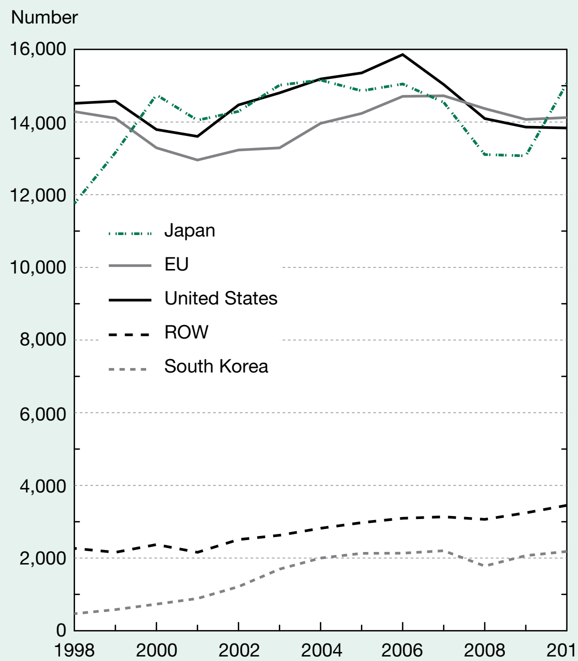
Patenting Valuable Inventions: Triadic Patents

Using patent counts as an indicator of national inventive activity does not differentiate between inventions of minor and substantial economic potential. Inventions for which patent protection is sought in three of the world's largest markets—the United States, the EU, and Japan—are likely to be viewed by their owners as justifying the high costs of filing and maintaining these patents in three markets. These *triadic patents* serve here as an indicator of higher-value inventions, although growing patent activity in China, India, South Korea, and other locations may limit the utility of this measure. The number of triadic patents is strongly correlated with expenditures on industry R&D, suggesting that countries with higher patenting activity make greater investments to foster innovation (OECD 2009:36).

Between 2000 and 2010, the number of triadic patents grew slightly from 45,000 to 49,000 (figure 6-34; appendix

Figure 6-34
Global triadic patent families, by selected region/country/economy: 1998–2010



EU = European Union; ROW = rest of world.

NOTES: Triadic patent families include patents applied in the U.S. Patent and Trademark Office, European Patent Office, and Japan Patent Office. Patent families are fractionally allocated among regions/countries/economies based on the proportion of the residences of all named inventors.

SOURCE: Organisation for Economic Co-operation and Development, Patents Statistics, http://stats.oecd.org/WBOS/index.aspx, Patents by Region database, accessed 15 January 2011. See appendix table 6-54.

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table 6-54). During this period, the United States, the EU, and Japan had roughly equal numbers of triadic patents.[27] South Korea's filings rose much faster than overall growth, resulting in its share of triadic patents doubling from 2% to 4%. Filings by all other countries remained at less than 1% of all triadic patents during this period.

Trade in Royalties and Fees

Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. Trade in intellectual property can involve patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary rights; broadcast rights and other intangible rights; and the rights to distribute, use, and reproduce general-use computer software. These transactions generate revenues in the form of royalties and licensing fees. Trade in royalties and fees is a rough indicator of technology transfer across the global economy and the international value of an economy's intellectual property. However, differences in tax policies and protection of intellectual property also likely influence the volume and geographic patterns of global trade in royalties and fees (Gravelle 2010:8; Mutti and Grubert 2007:112).

Global exports of royalties and fees were estimated at $241 billion in 2011 (figure 6-35). The United States, the EU, and Japan are collectively the largest global exporters, with a global share of 85%.

The United States is by far the world's largest exporter of royalties and fees, with exports of $121 billion and a large and growing surplus (figure 6-35). The volume and geographic patterns of U.S. trade in royalties and fees have been influenced by U.S.-based multinationals transferring their intellectual property to low-tax jurisdictions or their foreign subsidiaries to reduce their U.S. and foreign taxes (Gravelle 2010:8; Mutti and Grubert 2007:112). The EU is the second largest, with exports of $54 billion. The EU has a small deficit in trade of royalties and fees. Japan is the third largest, with exports of $29 billion, and has a substantial trade surplus.

Exports of major developing countries are much lower than those of developed countries (figure 6-36). Developing countries are typically net importers of royalties and fees as they seek to acquire technology from abroad to foster development of their economies. China is the largest developing country exporter of royalties and fees, with $743 million (figure 6-36). Brazil is the second largest, with $590 million, followed by India ($300 million). These three countries have had growing deficits in their trade of royalties and fees.

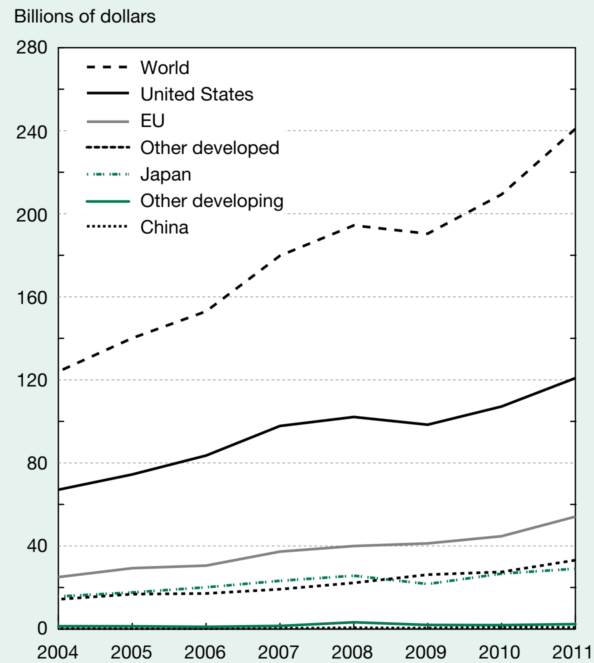
U.S. High-Technology Small Businesses

Many of the new technologies and industries seen as critical to U.S. innovation and economic growth are identified with small businesses. Many large HT businesses invest in and acquire small businesses as part of their efforts to develop and commercialize new technologies. Biotechnology, the Internet, and computer software are examples of industries built around new technologies in whose initial commercialization microbusinesses—those with fewer than five employees—played an important role. Trends in the number of microbusinesses in emerging or established HT sectors may point to innovative industries with future areas of growth. This section covers patterns and trends that characterize microbusinesses operating in HT industries as classified by the Bureau of Labor Statistics (BLS), which is different than OECD's HT classification. Two sources of financing for HT small businesses—venture capital and the U.S. government's SBIR—are also examined using data from Dow Jones and other sources.

Characteristics of Microbusinesses in U.S. High-Technology Industries

The number of microbusinesses in industries classified as HT by BLS is about 320,000, two-thirds of all firms operating in these industries (table 6-9; figure 6-37; appendix table 6-55).[28] Services account for 95% (300,000) of U.S. HT

Figure 6-35
Global exports of royalties and fees, by selected region/country/economy: 2004–11



EU = European Union.

NOTES: EU exports do not include intra-EU exports. Developed countries are classified as high-income economies by the World Bank. Developing countries are classified as upper- and lower-middle income and low income by the World Bank. Sum of regions/countries/economies does not add up to total due to rounding and discrepancies.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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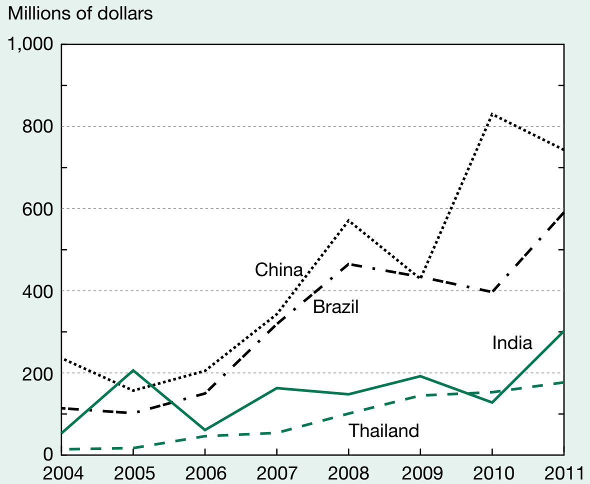
microbusinesses; manufacturing accounts for 4% (12,000), with the remainder in other industries (e.g., agriculture, mining, and construction). Similarly, services dominate employment in HT microbusinesses, with a very small share employed in manufacturing.

Figure 6-36
Exports of royalties and fees of selected developing countries: 2004–11



NOTE: Developing countries are classified as upper- and lower-middle income and low income by the World Bank.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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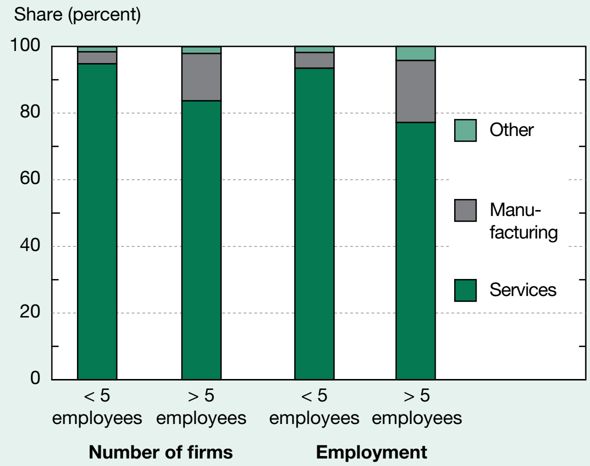
Figure 6-37
U.S. HT industries, by share of industry sector: 2010



HT = high technology.

NOTES: Firms with fewer than five employees include those reporting no employees on their payroll. A firm is an entity that is either a single location with no subsidiary or branches or the topmost parent of a group of subsidiaries or branches. HT industries are defined by the Bureau of Labor Statistics (BLS) by the basis of employment intensity of the technology-oriented occupations, based on the BLS Occupational Employment Survey of 2011. HT small business employment is a lower-bound estimate because employment data are not available for a few industries due to data suppression.

SOURCES: U.S. Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/econ/susb/, accessed 15 May 2013; Hecker DE. 2006. High-technology employment: A NAICS-based update, *Monthly Labor Review* 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 15 May 2013. See appendix table 6-55.

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Table 6-9
Number of firms and employment of U.S. HT microbusinesses, by selected industries: 2010

Industry	Number of firms	Employment
All industries	316,636	437,604
All manufacturing industries	11,512	20,683
Navigational, measuring, electromedical, and control instruments	1,645	3,025
Other general-purpose machinery	1,589	3,036
Industrial machinery	1,128	2,129
Semiconductors and other electronic components	1,121	1,954
All others	6,029	10,539
All services industries	300,259	408,968
Management, scientific, and technical consulting	117,678	140,953
Computer systems design and related	80,767	107,719
Architectural, engineering, and related	61,046	95,055
All others	40,768	65,241
All other industries	4,865	7,953

HT = high technology.

NOTES: Firms with less than 5 employees include those reporting no employees on their payroll. A firm is an entity that is either a single location with no subsidiary or branches or the topmost parent of a group of subsidiaries or branches. HT industries are defined by the Bureau of Labor Statistics (BLS) by the basis of employment intensity of the technology-oriented occupations based on BLS's 2011 Occupation Employment Survey. HT small business employment is a lower-bound estimate because employment data are not available for a few industries due to data suppression.

SOURCES: U.S. Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/econ/susb/, accessed 15 May 2013; Hecker DE. 2006. High-technology employment: A NAICS-based update, *Monthly Labor Review* 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 15 March 2013. See appendix table 6-55.

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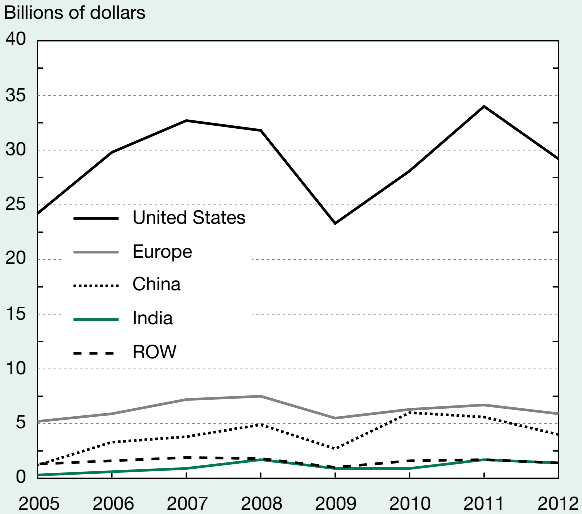
Three HT services—management, scientific, and technical consulting; computer systems design; and architectural and engineering—dominate HT services with a collective share of more than 80% of all firms and employment (table 6-9). In HT manufacturing, four industries—navigational, measuring, electromedical, and control instruments; other general purpose machinery; industrial machinery; and semiconductors—are large employers with a collective share of nearly 50%.

Entrepreneurial Investment in HT Small Businesses

Entrepreneurs seeking to start or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. (In this section, business denotes anything from an entrepreneur with an idea to a legally established operating company.) Often, entrepreneurs rely on friends and family for financing. However, when they need or can get access to larger amounts of financing, venture capital investment and SBIR financing are often critical to financing nascent and entrepreneurial HT businesses. This section examines patterns and trends of these two types of financing in the United States and internationally (venture capital only).

Venture capital investment. The United States accounted for $29 billion in venture capital, nearly 70% of global venture capital in 2012 (figure 6-38; appendix table 6-56). Europe and China are the next largest, accounting for $6 billion and $4 billion, respectively. Venture capital financing in India was $1 billion. Much of the financing occurring outside of the United States probably originates from U.S.-based venture capital firms.

Figure 6-38
Venture capital investment, by selected region/country/economy: 2005–12



ROW = rest of world.

NOTE: ROW consists of Canada and Israel.

SOURCE: Dow Jones, special tabulations (2013) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp.

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Between 2005 and 2012, global venture capital financing rose by 30% to reach $42 billion (figure 6-38). After falling sharply during the recession, venture capital bounced back to its pre-recession level in 2011 before falling $8 billion in 2012. Venture capital invested in the United States grew more slowly than outside the United States, with the result that the U.S. share of global venture capital fell from 75% to 70% (figure 6-38). The expansion of venture capital outside of the United States coincides with the globalization of finance, greater commercial opportunities in rapidly growing developing countries, and the decline of yields on existing venture capital investments in U.S. companies. In China, venture capital grew from $1 billion in 2005 to $4 billion in 2012, resulting in its global share more than doubling to reach 10% (figure 6-38). Venture capital investment in India grew from $300 million to $1.4 billion, with India's global share rising from 1% to 3%.

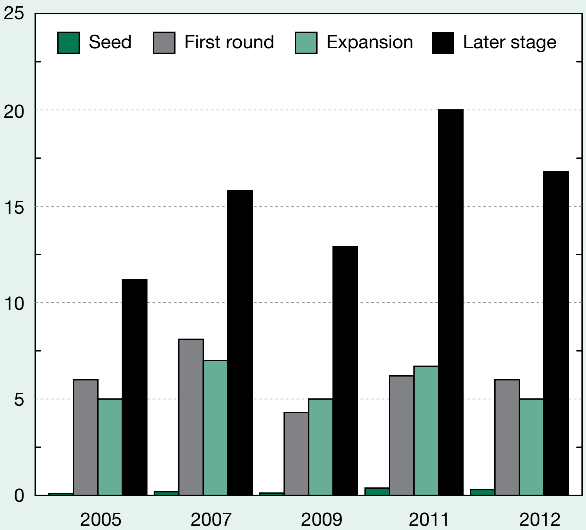
Venture capital investment is generally categorized into four broad stages of financing:

- **Seed** supports proof-of-concept development and initial product development and marketing.
- **First round** supports product development and marketing and the initiation of commercial manufacturing and sales.
- **Expansion** provides working capital for company expansion; funds for major growth (including plant expansion, marketing, or development of an improved product); and financing to prepare for an initial public offering (IPO).
- **Later stage** includes acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and management and leveraged buyouts provide funds to enable operating management to acquire a product line or business from either a public or a private company.

In 2012, later stage venture capital investment comprised 60% ($17 billion) of total U.S. venture capital investment, up from 50% in 2005 (figure 6-39; appendix table 6-56). Knowledgeable observers have attributed the shift to later-stage investment because of a desire for lower investment risk, a decline in yields on existing investments of venture capitalists, and a sharp decline in IPOs and acquisitions of venture capital–backed firms, which has required venture capital investors to provide additional rounds of financing.[29]

In contrast to the predominance of later-stage investment, investment in the seed stage, the earliest stage, amounted to 1% ($300 million) of total U.S. venture capital investment (figure 6-39; appendix table 6-56). Despite the amount tripling in value between 2005 and 2012, seed's share of venture capital investment remained at 1% or less. Investment in the first-round stage, which follows seed, represented 21% ($6.0 billion) of venture capital investment in 2012. Investment in this stage remained constant, resulting in its share falling 6 percentage points to 21% in 2012. Financing

Figure 6-39
U.S. venture capital investment, by financing stage: Selected years, 2005–12
Billions of dollars



NOTES: Seed consists of proof-of-concept development and initial product development and marketing. First round consists of product development and marketing and the initiation of commercial manufacturing and sales. Expansion consists of second-round financing that provides working capital for company expansion and financing to prepare for an initial public offering. Later stage includes acquisition financing and management and leverage buyouts.

SOURCE: Dow Jones, special tabulations (2013) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp. See appendix table 6-56.

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of the expansion stage, which follows first round, represented 18% ($5.0 billion) of venture capital investment in 2012. Investment in this stage stayed constant between 2002 and 2012, resulting in its share falling from 22% to 18%.

Five technologies—biopharmaceuticals, business support services, consumer information services, medical devices and equipment, and software—dominate U.S. venture capital financing (table 6-10). During 2009–12, these five technologies accounted for more than 60% of total and seed stage investment.

Software led these technologies in venture capital investment, receiving $19.2 billion in 2009–12 (table 6-10; appendix table 6-56). Total and early stage investment in software rose between 2005 and 2012, resulting in software's share of total investment remaining steady (23%) and its share of early stage investment increasing from 16% to 34%. Biopharmaceuticals was second, receiving $14.7 billion. Total investment in biopharmaceuticals fell from $4.0 billion in 2005 to $3.4 billion in 2012, resulting in its share falling from 17% to 12%. Seed stage financing dropped from $7 million to $6 million during this period. Consumer information services received $13.5 billion in 2009–12. Total venture capital investment in this technology area rose from less than $700 million in 2005 to $2.8 billion in 2012. Growth in early stage financing was also rapid, rising from less than $10 million to $79 million, resulting in its share more than doubling from 11% to 26%.

Small Business Innovation Research Financing. The U.S. federal government's SBIR program provides early stage public financing to help U.S. small or start-up

Table 6-10
U.S. venture capital investment, by selected financing stage and technology/industry: 2009–12
(Millions of U.S. dollars)

Technology/industry	2009	2010	2011	2012	2009–12 total
All financing stages					
All technologies/industries	23,291	28,131	34,006	29,208	114,636
Software	3,350	4,183	4,973	6,663	19,169
Biopharmaceuticals	3,820	3,466	4,043	3,380	14,709
Consumer information services	2,264	4,107	4,328	2,823	13,522
Business support services	2,248	2,748	4,261	3,698	12,955
Medical devices and equipment	3,060	2,551	3,403	2,765	11,779
Seed stage					
All technologies/industries	120	230	376	302	1,028
Software	22	44	128	102	296
Consumer information services	36	60	95	79	270
Business support services	18	39	46	23	126
Media and content	6	3	10	21	40
Medical software and information services	3	6	4	13	26

NOTES: Technologies are classified by Dow Jones. Seed stage consists of proof of concept and initial product development.

SOURCE: Dow Jones, special tabulations (2013) of VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp. See appendix table 6-56.

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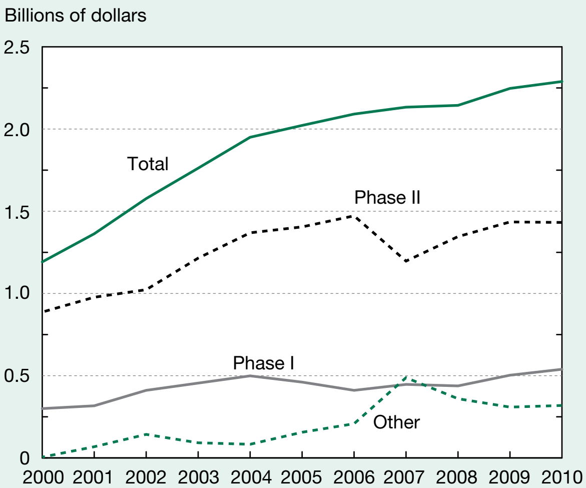
companies to commercialize technology derived from federal R&D. (For more information on SBIR, see chapter 4, "Small Business Innovation-Related Programs.") The SBIR program provides financing in two phases:

- Phase I funds the evaluation of the scientific and technical merit and feasibility of a company's new ideas.
- Phase II funds further scientific and technical review and requires a commercialization plan.

SBIR provided $2.3 million in financing for nearly 6,000 awards in 2010 (figure 6-40).[30] The majority of SBIR financing occurs in Phase II, which provided $1.4 million to fund more than 4,000 awards in 2010. The next largest financing stage, Phase I, provided $0.5 million for nearly 2,000 awards in 2010. The remainder ($0.3 million) provided funding for technical assistance, commercial outreach, and other activities. After nearly doubling from $1.1 million in 2000 to $2.0 million in 2004, SBIR financing grew far more slowly in the latter half of the decade to reach $2.2 million in 2010. Between 2000 and 2010, Phase II financing lagged the overall growth of SBIR financing, resulting in the share of Phase II declining from 77% to 64%. In contrast, Phase I's share of SBIR financing remained roughly steady at 20%–24% during this period.

Figure 6-40
SBIR investment, by financing phase: 2000–10



SBIR = Small Business Innovation Program.

NOTES: SBIR investment is by fiscal year. Investment is the amount budgeted by U.S. federal agencies for SBIR financing. Phase I evaluates the scientific and technical merit and feasibility of ideas. Phase II is subject to further scientific and technical review and requires a commercialization plan. Other includes technical assistance and commercial outreach.

SOURCE: SBIR Report Data, http://www.sbir.gov/awards/annual-reports, accessed 15 June 2013.

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Investment and Innovation in Clean Energy Technologies

The fifth section of this chapter examines clean energy and energy-conservation and related technologies. Clean energy, like KTI industries, has a strong link to S&T. Clean energy and energy-conservation and related technologies—including biofuels, solar, wind, nuclear, energy efficiency, pollution prevention, smart grid, and carbon sequestration—have become a policy focus in developed and developing nations. These technologies are KTI and thus are closely linked to scientific R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in many countries. Prompted by concerns over the high cost of fossil fuels and their impact on the climate, governments have developed various inducements, such as subsidies and tax incentives, and increased funding for clean energy R&D.

This section examines venture capital and total private financing data from Bloomberg New Energy Finance and public research, development, and demonstration (RD&D) data from the International Energy Agency (IEA). The IEA data discussed here cover RD&D. They are not comparable to the energy R&D data described in chapter 4, which focus on R&D.[31]

Commercial Investment

Global commercial investment in clean energy technologies, including early stage angel and venture capital investment and later-stage financing, was $160 billion in 2012 (figure 6-41).[32] Two technologies—wind and solar—dominate clean energy investment, with a combined share of 85% (figure 6-42).

Between 2005 and 2012, global clean energy investment rose from less than $30 billion to $159 billion (figure 6-41). The rapid rise of investment was interrupted by a dip during the global recession before climbing back to its level prior to the recession. This rise has been spurred by government policies to encourage clean energy financing and production and by falling costs in wind, solar, and other energy technologies. Global investment appears to have plateaued since the global recession due to several factors, including the sluggish global economy, cutbacks by many governments on subsidies, tax and other incentives for clean energy, and a substantial decline in natural gas prices due to hydraulic fracturing technologies.

Patterns and Trends in Developing Countries

In 2012, almost $100 billion in commercial investment in clean energy occurred in China and other developing countries, making up over 61% of global investment (figure 6-41). Clean energy financing in China was an estimated $61 billion, more than in any economy in the world (35% share of global investment). The comparable amount for other developing countries was $36 billion.

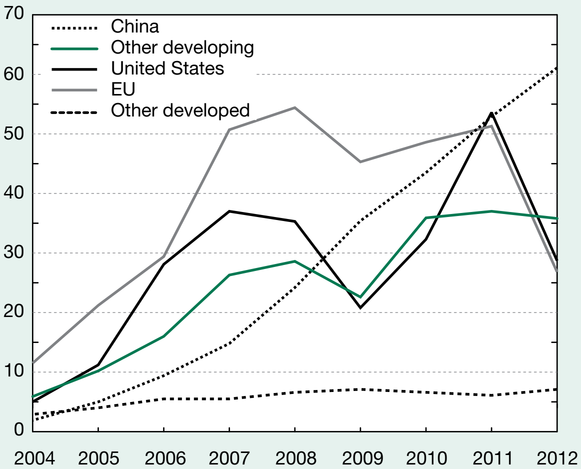
Between 2005 and 2012, clean energy investment in developing countries rose from $8 billion to nearly $100 billion (figure 6-41). The global share of developing countries climbed from about one-third of clean energy investment to nearly two-thirds during this period.

China was the primary driver of investment in developing countries; China's commercial investment rose exponentially from less than $2 billion in 2004 to $61 billion in 2012 (figure 6-41). The uninterrupted growth of clean energy investments in China reflects the government's policies targeted at wind and solar energy to make China a major world producer in these technologies and to reduce China's reliance on fossil fuels. Investment in wind energy, which was $28 billion in 2012, made up the largest share of China's investment between 2004 and 2012 (figure 6-43). Investment in solar also rose rapidly. It reached $27 billion in 2012, reflecting China's emergence as a major manufacturer of low-cost photovoltaic modules.

Clean energy investment in other developing countries has also risen rapidly, from $6 billion to $36 billion (figure 6-41). The rapid rise of investment in countries such as Brazil, India, Indonesia, and Mexico reflects the adoption of policies by these countries to encourage clean energy, lower costs relative to developed countries, and rapid economic growth and growing energy demand.

Figure 6-41
Financial new investment in clean energy technologies, by selected region/country/economy: 2004–12

Billions of dollars



EU = European Union.

NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Financial new investment includes private and public R&D, venture capital, private equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2013).

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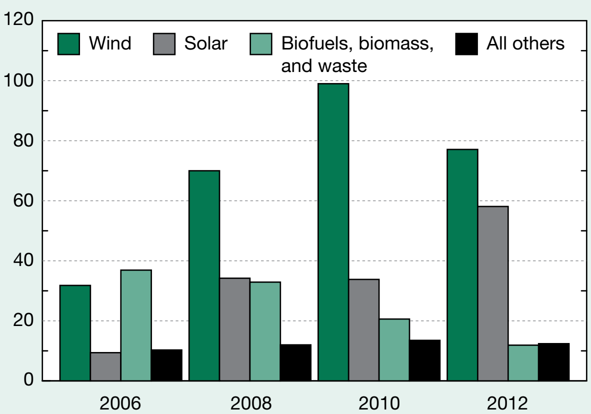
Figure 6-42
Financial new investment in clean energy technologies, by selected energy and technology: 2006–12

Billions of dollars



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Financial new investment includes private and public R&D, venture capital, private equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2013).

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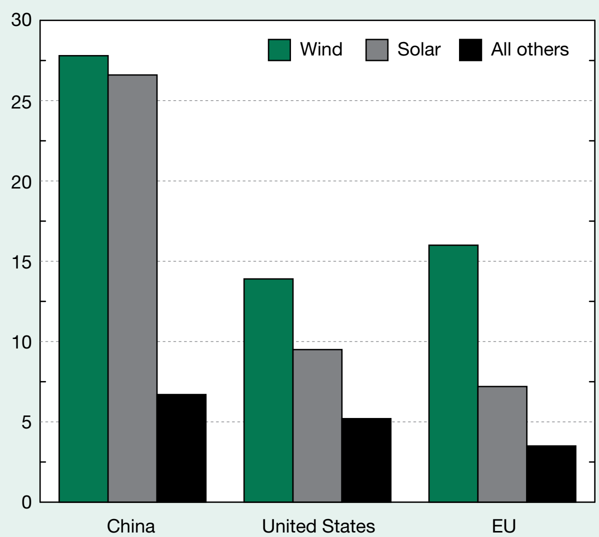
Figure 6-43
Financial new investment in clean energy technologies in China, the United States, and the EU, by technology: 2012

Billions of dollars



EU = European Union.

NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Financial new investment includes private and public R&D, venture capital, private equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2013).

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Patterns and Trends in Developed Economies

Investment in the United States, the EU, and other developed economies was $63 billion, 39% of global investment (figure 6-41). The United States and the EU, with from $27 billion to $29 billion each, tied as the second-largest locations of clean energy investment, behind China. Investment in other developed economies is much smaller, amounting to a collective $7 billion.

Between 2004 and 2012, clean energy investment in developed economies rose from $19 billion to $63 billion (figure 6-41). Investment has been volatile in the aftermath of the global recession. Investment rebounded in 2010 and reached a new high of $110 billion in 2011 before plunging to $63 billion in 2012, its lowest level since 2006.

After rising steadily prior to the global recession, U.S. investment fell sharply in 2008 before recovering to $32 billion in 2010, near its pre-recession level (figure 6-41). Investment spiked in 2011 to $45 billion before falling to $29 billion in 2012 due to the expiration of temporary financing provisions and subsidies. Wind and solar energy have led the growth of U.S. investment between 2004 and 2012 (figure 6-43). Wind investment reached $14 billion in 2012, closely followed by solar energy, which was $10 billion.

In the EU, the global recession had less impact on commercial investment compared to the United States (figure 6-41). However, investment fell by half in 2012 to $27 billion due to the EU's economic and financial crisis and sharp cutbacks in government support for solar and other clean energies in Germany, Spain, and the United Kingdom. Investment in solar energy in 2012 was $7 billion, less than half its level in 2008 (figure 6-43). Investment in wind energy was also down sharply.

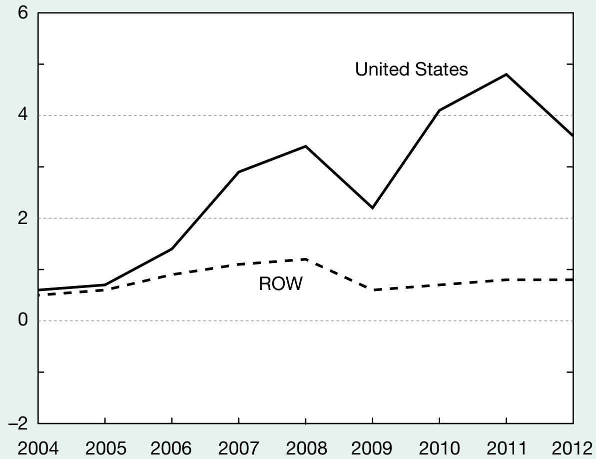
Venture Capital Investment

Venture capital investment is a useful indicator of market assessment of nascent and future trends in clean energy technologies. Global venture capital investment in clean energy was $4.4 billion in 2012, making up 3% of commercial financial investment (figure 6-44). The United States is the main location of venture capital financing for clean energy technologies, with more than 80% of global investment in 2012.

Among the technology areas, energy smart and efficiency technologies make up nearly half of venture capital financing (figure 6-45). The energy smart and efficiency category covers a wide range of technologies, from digital energy applications to efficient lighting, electric vehicles, and the smart grid that maximizes the energy efficiency of existing energy sources and networks. Two other technology areas—solar and biofuels—accounted for about 20% each of all venture capital financing.

After rising rapidly to reach $5 billion prior to the global recession, venture capital investment plunged in 2009. It then rebounded from $4 billion to $5 billion in 2010–12 (figure 6-44). Between 2004 and 2012, three technology areas—energy smart and efficiency, solar, and biofuels—led growth (figure 6-45). Biofuels grew the fastest among these technologies, but from a low base, to reach $0.9 billion. Solar rose from less than $0.2 billion to reach $1.0 billion. Energy smart and efficiency, the largest technology area, grew from $0.8 billion to $2.0 billion.

Figure 6-44
Global venture capital investment in clean energy technologies: 2004–12
Billions of dollars



ROW = rest of world.

NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2013).

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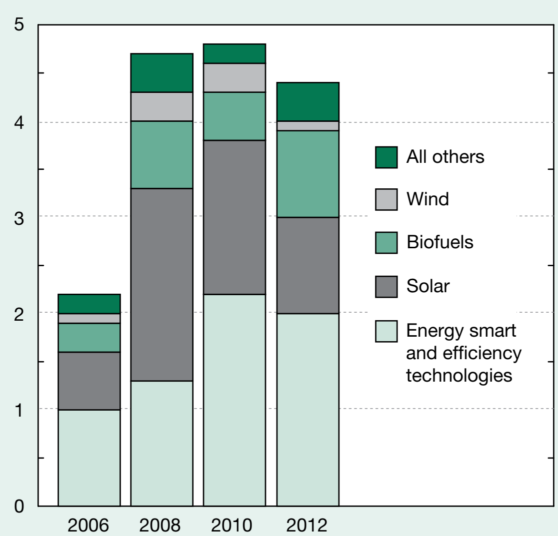
Figure 6-45
Global venture capital investment in clean energy technologies, by selected technology: 2006–12
Billions of dollars



NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2013).

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U.S. venture capital investment in the energy smart and efficiency and the solar areas is likely a result of several factors, including American Recovery and Reinvestment Act of 2009 (ARRA) funding of R&D in these technologies and U.S. loan guarantees for companies operating in these areas. In addition, energy efficiency technologies are less capital intensive than other clean energy technologies, have a shorter time horizon than most other energy technologies, can be applied to a wider range of energy products and services, and are less reliant on government incentives or subsidies that may be withdrawn.

Public Research, Development, and Demonstration Expenditures in Clean Energy Technologies

Major developed economies invested an estimated $13.0 billion on public RD&D in clean energy and nuclear technologies in 2011 (table 6-11; figure 6-46). Clean energy technologies include renewables (solar, wind, ocean), bioenergy, hydrogen, fuel cells, carbon capture and storage, energy efficiency, and other power and storage.[33]

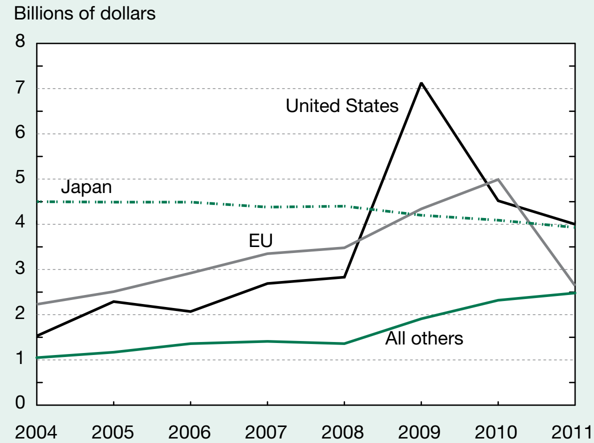
Nuclear energy was the largest area, receiving $5.6 billion in 2011, nearly one-third of total RD&D (table 6-11). The next two largest areas are energy efficiency and renewable energy (solar, wind, ocean, bioenergy), which received $3.6 and $2.4 billion, respectively. The fourth largest, other power and storage, received $1.1 billion.

The United States and Japan are the largest investors in clean energy and nuclear RD&D, with each spending $4.0 billion in 2012 (figure 6-46). The EU is the next largest, with expenditures of $2.6 billion. Three other countries—Canada, South Korea, and Australia—had significant expenditures. Canada's RD&D was $1 billion, and Australia and South Korea each spent between $500 million and $600 million.

Between 2004 and 2008, clean energy and nuclear RD&D rose steadily to reach $12 billion in 2008 before spiking up to $17.6 billion in 2009 due to stimulus spending in the United States and the EU (table 6-11; figure 6-46). Clean energy and nuclear RD&D fell in 2010 and 2011 with the fading of stimulus spending to reach $13.1 billion in 2011. Trends among the individual technology areas varied between 2004 and 2011:

- CO_2 capture and storage had the fastest growth, rising from $100 million to $1.1 billion.

Figure 6-46
Government RD&D expenditures of selected developed countries/economies in clean energy and nuclear technologies: 2004–11



EU = European Union; RD&D = research, development, and demonstration.

NOTES: Clean energy and nuclear technologies include solar, wind, bioenergy, nuclear, fuel cells, hydrogen, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. All others include Australia, Canada, and South Korea.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 January 2013.

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Table 6-11
Government RD&D of selected developed countries in clean energy and nuclear technologies, by technology area: Selected years, 2004–11
(Billions of dollars)

Year	All clean energy and nuclear technologies	Nuclear	Energy efficiency	Renewable energy	Hydrogen and fuel cells	Other power and storage	CO_2 capture and storage
2004	9.3	5.2	1.5	1.3	0.6	0.5	0.1
2008	12.0	5.7	2.4	1.9	1.0	0.6	0.4
2009	17.6	5.7	4.3	4.1	0.9	1.6	1.0
2010	15.9	5.7	3.9	3.5	0.8	0.9	1.0
2011	13.0	4.6	2.4	3.6	0.6	0.8	1.1

RD&D = research, development, and demonstration.

NOTES: Clean energy and nuclear technologies include solar, wind, bioenergy, nuclear, fuel cells, hydrogen, CO_2 capture and storage, other power and storage, and energy efficiency. Detail may not add to total because of rounding. Countries included are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Netherlands, Norway, Poland, Portugal, Slovakia, South Korea, Spain, Sweden, Switzerland, United Kingdom, and United States.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 March 2013.

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- Spending on renewable energy nearly tripled to reach $3.6 billion.
- Energy efficiency expenditures rose by 50% to reach $2.4 billion.
- Nuclear energy declined from $5.2 billion to $4.6 billion.

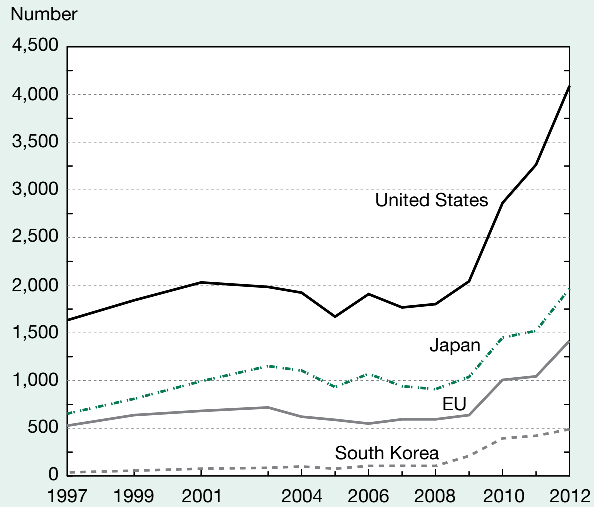
The United States outpaced the EU and Japan in growth of clean energy and nuclear RD&D during this period (table 6-12; figure 6-46). U.S. RD&D rose from $1.5 billion in 2004 to $2.8 billion in 2008 before surging to $7.1 billion in 2009 due to ARRA spending. Renewable and energy efficiency received the bulk of ARRA spending, which temporarily increased spending in each technology area by about $1.5 billion. U.S. RD&D dropped in 2010 and 2011 to reach $4.0 billion, $2.5 billion higher than its RD&D in 2004. The EU's RD&D increased from $2.2 billion in 2004 to reach a stimulus-induced high of $5.0 billion in 2010 before dropping to $2.6 billion in 2011, still 18% higher than its level in 2004. Japan's RD&D declined from $4.5 billion to $3.9 billion.

Patenting of Clean Energy and Pollution Control Technologies

USPTO patents granted in clean energy and pollution control technologies can be classified using a taxonomy developed for this purpose. The taxonomy classifies patents involving bioenergy, nuclear, wind, solar, energy storage, smart grid, and pollution mitigation. The number of patents in these technologies jumped to a record high in 2012, which could reflect USPTO efforts to speed up processing of applications (figure 6-47; appendix table 6-57).[34] (For a more detailed description of how this taxonomy identifies clean energy and pollution control patents, see the sidebar in chapter 5, "Identifying Clean Energy and Pollution Control Patents.") U.S. resident inventors were granted slightly less than half of the 8,800 clean energy and pollution control technology patents in 2012, continuing the advantage of non-U.S. inventors in these fields since 2003.

Among non-U.S. inventors, Japan, the EU, and South Korea, in that order, are the main recipients of U.S. patents for clean energy and pollution control technologies, with a collective share of 44% of total patents granted (figure 6-47;

Figure 6-47
USPTO patents in alternative energy and pollution control technologies, by selected region/country/economy of inventor: Selected years, 1997–2012



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies are classified by The Patent Board.™ Patent grants are fractionally allocated among regions/countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ Proprietary Patent database, special tabulations (2013). See appendix table 6-57.

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Table 6-12
U.S. government RD&D expenditures on clean energy and nuclear technologies: 2007–11
(Millions of dollars)

Year	All clean energy and nuclear technologies	Energy efficiency	Renewable energy	Nuclear energy	Hydrogen and fuel cells	Other power and storage technologies
2007	2,690	585	594	898	343	140
2008	2,831	692	468	1,008	335	127
2009	7,131	2,196	2,280	871	368	951
2010	4,519	1,422	1,338	907	340	281
2011	3,996	882	1,161	1,225	260	178

RD&D = research, development, and demonstration.

NOTE: Clean energy and nuclear technologies include solar, wind, bioenergy, nuclear, fuel cells, hydrogen, CO_2 capture and storage, other power and storage, and energy efficiency.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 March 2013.

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appendix table 6-57). Japan received 22%, and EU inventors received 16%. South Korean inventors received 6% of total patents, up from 2% in 2003. Patents granted to inventors in China and Taiwan have been increasing rapidly, although from a low base. In 2012, China's and Taiwan's shares of total patents were 2% each, up from 1% or less in 2003.

Clean energy and pollution control technology patents comprise four broad areas: alternative energy, with 5,000 patents granted; energy storage, with 1,000 patents; smart grid, with 800 patents; and pollution mitigation, with 2,000 patents (table 6-13; appendix tables 6-58–6-61). The proportion of alternative energy patents rose from 27% in 1997 to 59% in 2012, with major share gains by fuel cells and solar patents. Pollution mitigation technologies declined from 56% to 23%, driven by share losses of air and water quality.

Patent technology activity indexes measure the world share of a region, country, or economy in clean energy and clean technologies relative to its world share in patents in all technologies. A ratio greater than 1 signifies that patents by a region, country, or economy are concentrated in a particular technology (table 6-14).

In alternative energy patents, the U.S. has a high concentration in bioenergy and solar technologies and relatively low patent activity in fuel cells, hybrid vehicles, and wind energy (table 6-14; appendix tables 6-62–6-66). The EU has relatively high concentrations in bioenergy, wind, and nuclear and a relatively low concentration in electric hybrid technologies (appendix table 6-67). Japan has a high concentration of patents in electric hybrid technologies and fuel cells but relatively low activity in bioenergy, solar, and wind. South Korea has a high concentration in fuel cells but low concentrations in bioenergy, solar, and wind.

The United States and the EU have relatively low concentrations of patents in energy storage because of their low activity in battery technology, but this is an area of high concentration for Japan and South Korea (table 6-14; appendix tables 6-59 and 6-68). Despite its overall low concentration of patents in energy storage, the United States has a high concentration of patents in hydrogen power and storage (appendix table 6-69).

In smart grid, the United States has a high concentration of patents, the EU has a slightly above-average concentration, and Japan and South Korea have relatively low concentrations (table 6-14; appendix table 6-60).

In pollution mitigation technologies, the United States has a slightly above-average concentration of patents, with high concentrations in carbon capture and storage and in cleaner coal (table 6-14; appendix tables 6-61, 6-70, and 6-71). The EU has a particularly high concentration of patents in air pollution and a high concentration in carbon capture and storage (appendix table 6-72). Japan has average patenting activity in this area, with high concentrations in air pollution and in carbon capture and storage. South Korea has relatively low concentrations in all pollution mitigation technologies (appendix tables 6-73–6-75).

Table 6-13
USPTO patents granted in alternative-energy and pollution-control technologies, by technology area: Selected years, 1997–2012

Technology	1997	2002	2007	2010	2012
All alternative-energy and pollution-control technologies	3,087	4,094	3,701	6,260	8,834
Alternative energy	846	1,522	1,605	3,094	5,214
Bioenergy	52	74	101	226	564
Electric and hybrid vehicles	189	405	396	543	896
Fuel cells	95	374	549	1,093	1,143
Solar	212	397	261	671	1,472
Wind	29	65	173	362	856
All others	269	207	125	199	283
Energy storage	349	576	508	989	1,098
Batteries	220	329	227	523	632
Hydrogen production and storage	77	141	186	307	284
All others	52	106	95	159	182
Pollution mitigation	1,719	1,856	1,382	1,916	2,064
Air	696	877	731	1,084	1,183
Capture and storage of carbon and other greenhouse gases	57	89	64	157	215
Cleaner coal	96	61	41	171	240
Water	271	371	306	321	311
All others	599	458	240	183	115
Smart grid	291	304	366	543	811

USPTO = U.S. Patent and Trademark Office.

NOTES: Alternative-energy and pollution-control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, bioenergy, hydropower, wave, tidal, ocean, geothermal, and electric and hybrid automobiles. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gasses. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Technologies are classified by The Patent Board.™ The sum of individual technologies may exceed broad areas, and the sum of the broad categories may exceed the total because some of the patents are assigned to multiple individual technologies or broad areas.

SOURCE: The Patent Board,™ special tabulations (2013) of the Proprietary Patent database. See appendix tables 6-57–6-75.

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Table 6-14
Patenting activity in alternative-energy and pollution-control technologies, by selected country/economy: 2009–12
(Activity index)

Technology	United States	EU	Japan	South Korea
All alternative-energy and pollution-control technologies	0.97	1.12	1.10	1.11
Alternative energy	0.95	1.21	1.10	1.06
Bioenergy	1.45	1.04	0.22	0.21
Fuel cells	0.71	0.77	1.83	2.18
Hybrid electric	0.79	0.83	2.00	0.97
Solar	1.14	0.97	0.69	0.86
Wind	0.86	2.81	0.37	0.08
Energy storage	0.71	0.53	1.68	3.06
Batteries	0.40	0.39	2.11	4.67
Hydrogen power and storage	1.15	0.75	0.95	1.22
Smart grid	1.26	1.08	0.43	0.50
Pollution mitigation	1.07	1.25	0.97	0.44
Air	0.94	1.43	1.36	0.42
Capture and storage of carbon and other greenhouse gases	1.33	1.11	0.37	0.45
Cleaner coal	1.50	0.70	0.31	0.18

EU = European Union.

NOTES: Alternative-energy and pollution-control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, bioenergy, hydropower, wave, tidal, ocean, geothermal, and electric and hybrid automobilies. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Technologies are classified by The Patent Board.™ Patent grants are fractionally allocated among countries/economies on the basis of the proportion of the residences of all named inventors. The EU includes current member countries. The activity index consists of the ratio of the countries'/economies' share of the indicated technology to the countries'/economies' share of the total grants. A ratio of greater than 1.00 signifies more active patenting in the selected technology; a ratio of less than 1.00 signifies less active patenting.

SOURCE: The Patent Board,™ special tabulations (2011) of the Proprietary Patent database. See appendix tables 6-57–6-75.

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Conclusion

The U.S. economy continues to be the leading global economy in technology-based industries, as measured by its overall performance, market position in these industries, and position in patenting and other measures of innovation-related activities.

The strong competitive position of the U.S. economy overall is tied to continued U.S. global leadership in many KTI industries. The United States continues to hold the dominant market position in commercial KI services, which account for nearly one-fifth of global economic activity, and in HT manufacturing industries. The U.S. trading position in commercial KI services and licensing of patents and trade secrets remains strong, as evidenced by the continued U.S. surpluses in these areas. The United States is the leading source of RD&D and venture capital financing of clean energy technologies.

The overall U.S. ranking notwithstanding, its market position in almost all of these industries has not been improving; in many cases, it has slipped. China, the second-largest producer in HT manufacturing industries, has narrowed its gap with the United States. U.S. production and employment have fallen sharply in the HT manufacturing industries of communications, computers, and semiconductors, coinciding with U.S. companies moving assembly and other activities to China and other countries. The U.S. trade position in these products has shifted to deficit because, although exports have increased, imports have increased even more. In addition, productivity growth of the U.S. economy has slowed in the 2000s relative to the 1990s.

For much of the 2000s, the EU's position was similar to that of the United States—relatively strong overall economic performance, with a slowdown in productivity and flatlining or slight declines in its market position in KTI industries. During this period, Japan's economy showed less dynamism compared with the economies of the United States and the EU, and its market position declined steeply in many KTI industries. Japan's loss of market position in HT manufacturing industries was due, in part, to Japanese companies shifting production to China and other Asian economies.

Among large developing countries, China's progress clearly stands out. China has become a leading provider of commercial KI services and the second-largest global producer in HT manufacturing industries. China has become the largest global exporter in HT manufacture products and has developed surpluses in trade of HT manufacturing products and commercial KI services. China has become the world's largest source of commercial financing for clean energy and a leading producer in the solar industry. China has led the acceleration of productivity growth in developing countries over the last decade. However, China's indigenous capability in KTI industries and other indicators is uneven. Much of China's HT manufacturing output is controlled by MNCs that import higher-value components from other countries. Chinese companies have made limited progress in more technologically advanced and higher-end manufacturing activities. In addition, China's share of USPTO and economically valuable patents remains very small.

Other developing economies—including Brazil, India, and Indonesia—are showing rapid progress in their overall economic growth and technological capabilities. Their market positions in many KTI industries have strengthened, coinciding with their rapid economic growth and development. Productivity growth has accelerated in most developing countries.

Led by China, KTI industries in developing countries have grown much faster than developed economies in the aftermath of the recession. The United States has generally fared better than other developed countries in most KTI industries in the aftermath of the 2008–09 global recession. Although productivity growth has been weak, the United States continues to grow faster than most other developed countries. The EU's market position in KTI industries has eroded because of the EU's economic and financial problems. Japan continues to lose market share in many KTI industries.

Notes

1. See the Organisation for Economic Co-operation and Development (OECD) (2001) for a discussion of classifying economic activities according to degree of "knowledge intensity." Like all classification schemes, the OECD classification has shortcomings. For example, knowledge- and technology-intensive (KTI) industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allows researchers and analysts to trace, in broad outline, the worldwide trends toward greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

2. In designating these high-technology (HT) manufacturing industries, the Organisation for Economic Co-operation and Development (OECD) estimated the degree to which different industries utilized R&D expenditures made directly by firms in these industries and the R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have R&D intensities equal to or greater than those of industries designated by OECD as HT manufacturing. For additional perspectives on OECD's methodology, see Godin (2004).

3. See Atkinson and McKay (2007:16–17) for a discussion of and references to the impact of information technology on economic growth and productivity.

4. See Mudambi (2008) and Reynolds (2010) for a discussion on the shift to knowledge-based production and geographical dispersion of economic activity.

5. Data on the health care sector include social services.

6. See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for discussions of information and communications technologies and general-purpose technologies.

7. These information and communications technologies (ICT) infrastructure indexes originate from the Connectivity Scorecard, which has developed a variety of ICT indexes for developed and developing countries. The ICT infrastructure indexes are benchmarked against the best-in-class country among developed and developing countries. The business ICT infrastructure index is composed of metrics on business hardware and software and penetration of business lines. The consumer infrastructure index is composed of indicators on penetration of telephone lines and broadband. The government infrastructure index is composed of metrics related to e-government capacity and the share of schools connected to the Internet. More information on the methodology can be found at http://www.connectivityscorecard.org/methodology/.

8. Gross domestic product (GDP) per person employed is an imprecise measure of labor productivity. For example, labor productivity using this measure is skewed in countries that are major petroleum exporters because their GDP is boosted by their petroleum exports, with little input from labor.

9. See Jensen (2012) for a discussion of U.S business services firms helping to build infrastructure in developing countries.

10. See Williamson and Raman (2011) for a discussion of China's acquisition of foreign companies.

11. See *Economist* (Coming home 2013) for a discussion of multinational firms choosing to have more of their manufacturing take place in developed countries.

12. Commercial knowledge-intensive services and goods trade does not correspond to commercial knowledge- and technology-intensive industries because industry and trade data are collected on different bases. Industry production data are classified by primary industry, and trade data are classified by product or service.

13. Data on services exports are available from the World Trade Organization (2013).

14. India's export share is for 2009; 2010 data are not available.

15. Data for China's trade balance in commercial KI services are available from the World Trade Organization (2013).

16. Data for India's trade balance in commercial KI services are available from the World Trade Organization (2013).

17. Data on commercial KI exports by country are available from the World Trade Organization (2013).

18. The U.S. trade balance is affected by many other factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies and trade restrictions between the United States and its trading partners.

19. The 10 technology areas are advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications technology, life sciences, optoelectronics, nuclear, and weapons. More information on collection, definition, and measurement of advanced technology products trade data can be found at http://www.census.gov/foreign-trade/guide/sec2.html.

20. The Asia and Pacific region includes Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, and Thailand.

21. The National Science Foundation (NSF) Business R&D and Innovation Survey's (BRDIS's) definition of innovation is very similar to the Organisation for Economic Co-operation and Development definition. For more information, see NSF, BRDIS, http://www.nsf.gov/statistics/srvyindustry/about/brdis/.

22. Business R&D and Innovation Survey data are not available for the entire U.S. service sector.

23. Two legal concepts define who has the right to the grant of a patent—*first to file* and *first to invent*. In a first-to-file system, the patent is granted to the first person to file for protection. In the first-to-invent system, the patent is granted to the person who is determined to be the first inventor. The first-to-file system is used in all countries, including the United States, which switched to a first-to-file system in March 2013 after the enactment of the America Invents Act of 2011.

24. U.S. patent law states that any person who "invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent." The law defines *nonobvious* as "sufficiently different from what has been used or described before that it may be said to be nonobvious to a person having ordinary skill in the area of technology related to the invention." These terms are part of the criteria in U.S. patent law. For more information, see the U.S. Patent and Trademark Office, "What Is a Patent?" (http://www.uspto.gov/patents/index.jsp#).

25. The Japan Patent Office is also a major patent office but has a much smaller share of foreign patents than the U.S. Patent and Trademark Office and the European Patent Office.

26. The Business R&D and Innovation Survey data are collected from a sample of U.S. firms, whereas the U.S. Patent and Trademark Office data are from administrative records of all U.S inventors, including individuals and nonprofits.

27. Triadic patent families with coinventors residing in different countries are assigned to their respective regions, countries, or economies on a fractional-count basis (i.e., each region, country, or economy receives fractional credit on the basis of the proportion of its inventors listed on the patent). Patents are listed by *priority year*, which is the year of the first patent filing. Data for 1998–2003 are estimated by the Organisation for Economic Co-operation and Development.

28. The high-technology (HT) definition used here is from the Bureau of Labor Statistics and differs from that used in earlier sections. See Hecker (2005) for a definition and the methodology for determining HT industries.

29. Another possibility is that the behavior of venture capital investors changed because fewer opportunities for attractive risky investments were available in the 2000s than in the 1990s.

30. Data on number of awards are available at http://www.sbir.gov/awards/annual-reports.

31. The International Energy Agency (IEA) manual states: "The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that (i) it focuses on energy related programmes only; (ii) it includes 'demonstration projects'; and (iii) it includes state owned companies. . . . The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD) collected by the OECD Directorate for Science, Technology, and Industry for the socio-economic objective 'Production, distribution and rational utilisation of energy'" (IEA 2011:16–17).

32. Bloomberg's data include investment in renewable energy, biofuels, energy efficiency, smart grid and other energy technologies, carbon capture and storage, and infrastructure investments targeted purely at integrating clean energy. Investment in solar hot water, combined heat and power, renewable heat, and nuclear are excluded, as are the proceeds of mergers and acquisitions (which do not contribute to new investment).

33. The International Energy Agency has no official definition of clean energy. This discussion includes public research, development, and demonstration in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, CO_2 capture and storage, and other power and storage technologies.

34. The U.S. Patent and Trademark Office initiated a green technology pilot program on 7 December 2009 that expedites processing of some applications related to green technologies. For more information, see http://www.uspto.gov/patents/init_events/green_tech.jsp.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Commercial knowledge-intensive (KI) services: KI that are generally privately owned and compete in the marketplace without public support. These services are business, communications, and financial services.

Company or firm: A business entity that is either in a single location with no subsidiaries or branches or the topmost parent of a group of subsidiaries or branches.

European Union (EU): As of June 2013, the EU comprised 27 member nations: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Croatia joined the EU in July 2013. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all 28 members; data on the EU from other sources are limited to the 27 nations that were members as of June 2013.

Foreign direct investment: Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

High-technology (HT) manufacturing industries: Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

Hydraulic fracturing: The procedure of fracturing rock by a pressurized liquid to extract oil, gas, and other hydrocarbons that formerly had been inaccessible with conventional technologies. The slang term for hydraulic fracturing is "fracking."

Information and communications technologies (ICT) industries: A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors, and two knowledge-intensive service industries, communications and computer services, which is a subset of business services.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from European Union (EU) countries to other EU countries.

Knowledge- and technology-intensive (KTI) industries: Those that have a particularly strong link to science and technology. These industries are five service industries, financial, business, communications, education, and health, and five manufacturing industries, aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

Knowledge-intensive (KI) industries: Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, communications, education, financial, and health services.

Normalizing: To adjust to a norm or standard.

Not obvious: One criterion (along with "new" and "useful") that an invention must meet to be patentable.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by gross domestic product (GDP) or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Purchasing power parity (PPP): Procedure that normalizes currency exchange rates based on the funds required to purchase an equivalent market basket of goods in different countries.

R&D intensity: The proportion of R&D expenditures to the number of technical people employed (e.g., scientists, engineers, and technicians) or the value of revenues.

Triadic patent: A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

Utility patent: A type of patent issued by the U.S. Patent and Trademark Office for inventions, including new and useful processes, machines, manufactured goods, or composition of matter.

Value added: A measure of industry production that is the amount contributed by a country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value chain: A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Venture capitalist: Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

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